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Effect of Head Size on the Mechanical and Tribological Performance of Metal-on-Polyethylene Bearings, Under Conditions of Adverse Surgical Positioning and Edge Loading

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Introduction and Aims

Previous studies have shown that edge loading driven by separation due to mismatch between the centre of rotation of the head and the cup leads to increased deformation and wear at the rim. While it is recognised that larger head sizes may reduce the risk of dislocation, the effect of head size on the severity of edge loading, polyethylene damage, deformation and wear is not known. The aim of this study was to assess the effect of hip bearing diameter on the occurrence and severity of edge loading, deformation and wear of metal-on-polyethylene bearings

Methods

Two metal-on-polyethylene (MoP) bearing sizes (28mm and 36mm M-Spec™ metal head and Marathon® liners, 48mm and 56mm liner outer diameter respectively, DePuy Synthes Joint Reconstruction) were used in this study. The mechanical and tribological performance were assessed using a new two-stage approach for evaluating joint replacement using the Prosim EM13 (Figure 1). Stage 1 comprised a biomechanical study which considered variations in rotational positioning (45°, 55° and 65° inclination angles) and translational mismatches in the medial-lateral axis (1, 2, 3 and 4 (mm)). In stage two of this study, the wear and deformation were assessed by applying a standard gait cycle (ISO 14242-1) under two conditions: firstly no mismatch existed between the head and the cup and secondly with edge loading condition driven by separation where a 4mm mismatch was introduced between the femoral head and the cup, and the cup was inclined at 65° (*in vivo* equivalence). For stage one, each test (n=3) was run for 500 cycles and the dynamic separation displacement between the head and cup was measured in the medial-lateral axis and the maximum load at the rim determined. For stage two, each conditions (n=6) was run for three million cycles. The lubricant used was new-born calf serum (25% v/v). Gravimetric and geometric assessments were completed using a microbalance and CMM respectively.

Results

There was no difference in the level of dynamic separation displacements between the 28mm and 36mm bearings across the range of conditions studied (Figure 2). The wear rate of both bearing sizes were similar under standard (no edge loading) conditions (11.2±0.9 mm^3/million cycles for 28mm bearings and 12.0±1.4 mm^3/million cycles for 36mm bearings). The mean wear rate for the 28mm MoP bearings (±95% confidence limits) under 4mm translational mismatch at three million cycles was 20.7±1.9 mm^3/million cycles. This was similar (p=0.1) to that obtained for 36mm bearings (23.0±2.4 mm^3/million cycles) when tested under the same conditions. There was also no difference in the maximum penetration depth at the rim, 0.28±0.04 mm for both bearing sizes at 3 million cycle (Figure 3).

Conclusions

This study confirmed that variation in surgical positioning and edge loading causes increased deformation and wear of polyethylene at the rim of the acetabular cup in both size 28mm and 36mm bearings. However there was no difference in the severity of edge loading or the levels of deformation and wear between the two head sizes for the components studied.

References

[1] O'Dwyer Lancaster-Jones,et.al.2017,JBMR-B.

Figures

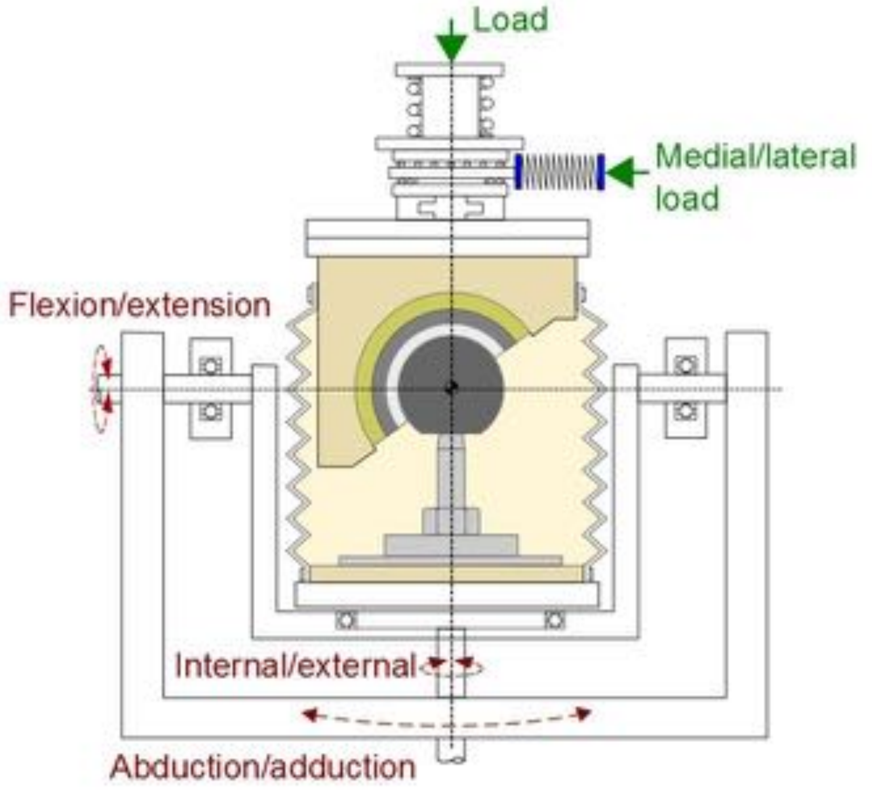

Figure 1: Schematic representation of one station of the six-station electromechanical hip joint simulator (EM13, ProSim, Simulation Solution, UK).

Figure 1

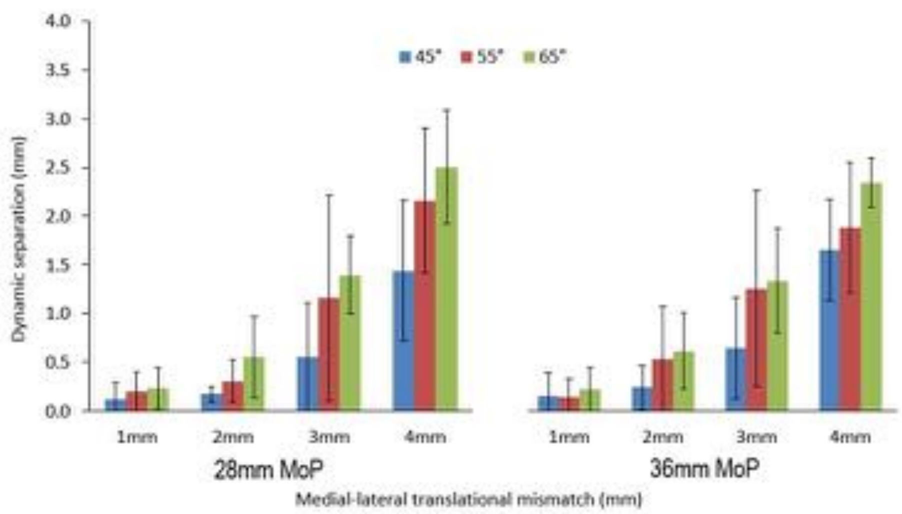

Figure 2: Mean dynamic separation displacement (±95% confidence limits) for 28mm and 36mm metal-on-polyethylene bearings tested under 1-4mm translational mismatch with 45°-65° cup inclination angle with 100N/mm spring constant and 70N swing phase load with ISO 14242-1 gait inputs.

Figure 2

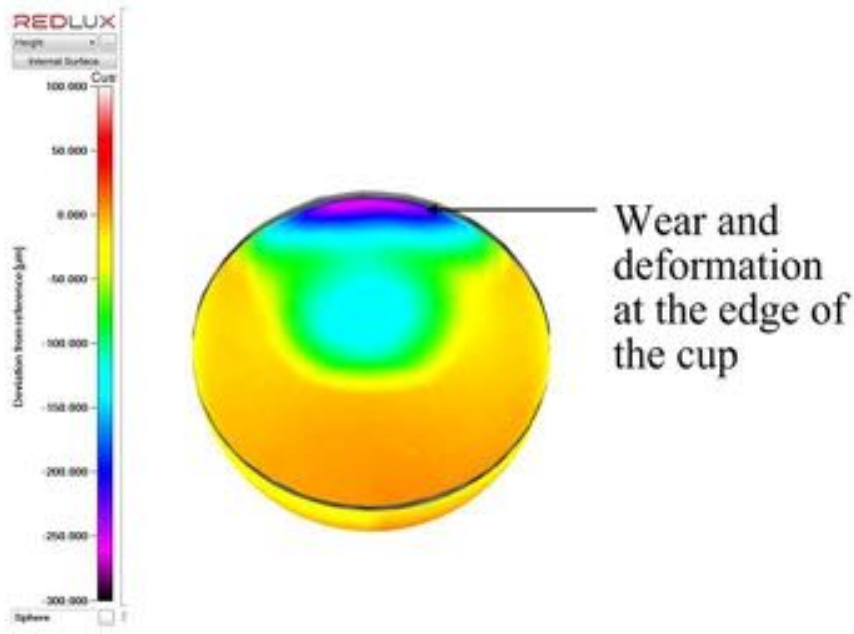

Figure 3: The deformation observed on the rim of polyethylene acetabular cups due to edge loading driven by dynamic separation conditions

Figure 3

#5646

The in Vivo Measured Temperature Increase in Total Hip Joint Replacement During Level Walking

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Introduction

Friction between head and cup is a primary factor for survival of total hip joint replacement (THR) and its gliding surfaces. In up to 40% of all revisions, the cup or inlay must be replaced as result of friction-induced wear [1]. Aim of the study was to measure the friction-induced temperature increase in vivo in THR and to identify possible individual parameters of influence.

Methods

For the in vivo measurement, an instrumented implant with an Al_2O_3/XPE-pairing and an integrated temperature sensor was used [Fig. 1] [2]. Ten patients were provided with such an instrumented implant.

Up to now, long time measurements were performed on six of these patients (Ø63y, Ø89kg). During these measurements, the subjects walked Ø60min on a treadmill with 4km/h. The investigation was performed Ø61 (43-70) months post operatively. Short time (Ø3min) in vivo load measurements during walking on treadmill were already available from the other four patients. These data were used to calculate the peak temperatures after 60mins of walking by using a model, based on the long time measurements.

Results

The peak values of the friction-induced temperature increase were achieved in vivo after 30min (H7R) to 70min (H2R), with peak temperatures between 1.5°C (H6R) to 4.8°C (H7R) [Fig. 2]. These maximum values were similar to those already observed in other patients [3]. The in vivo measured peak values of the friction-induced temperature increase after long time walking on a treadmill with respect to the implant orientation are shown in Fig. 3 as points and the calculated peak values as circles.

First analyses have shown that the individual implant orientations seem to have an influence [Fig. 3] on the friction-induced increase of the joint temperature during walking, but also the patient's age.

Discussion

The gliding partners and joint lubrication directly influence friction in artificial hip joint replacements and thus the friction-induced temperature increase. Analyses of the in vivo acting joint friction during walking have shown that there is an increase in friction over the course of each gait cycle after contralateral toe off [4]. This can be explained by a decrease in the lubricating film thickness due to the pressing out of the synovia from the joint space. During load reduction of the joint in the swing phase, the fluids are transported back into the joint space. Thus, the level of joint friction at the beginning of the next gait cycle depends on the return transport of the synovia.

The influence of the sum anteversion angle (ΣAV) on friction-induced temperature increase (Fig. 3) can therefore be explained mechanically: The ΣAV determines the functional joint roofing and the position of the load-transferring zone into the joint socket.

The larger the ΣAV, the more it shifts towards the edge of the socket, and the shorter the path for the return transport of the synovium.

References

[1] Report Can. Inst. Health, 2008; [2] Damm et. al 2010; [3] Bergmann et. al 2001; [4] Damm et. al, 2015

Figures

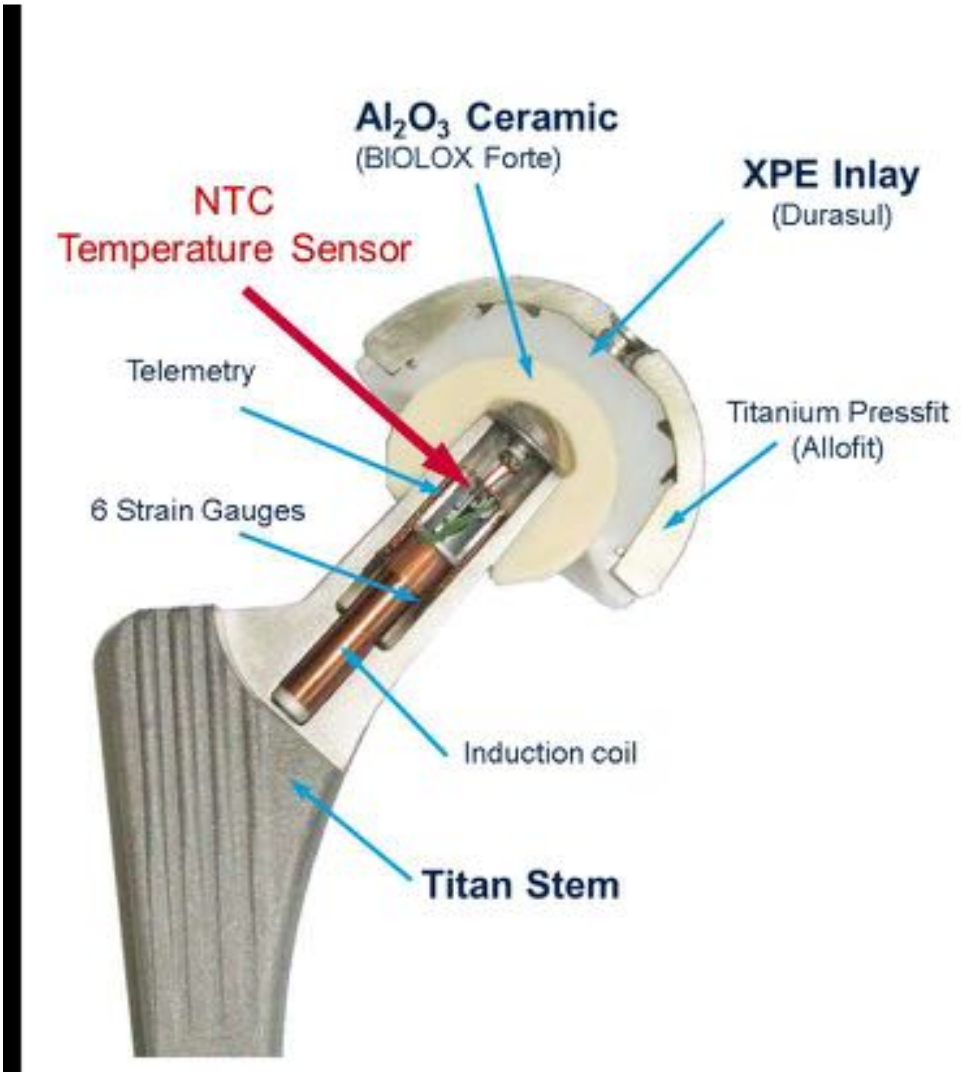

Figure 1: Instrumented hip implant

Figure 1

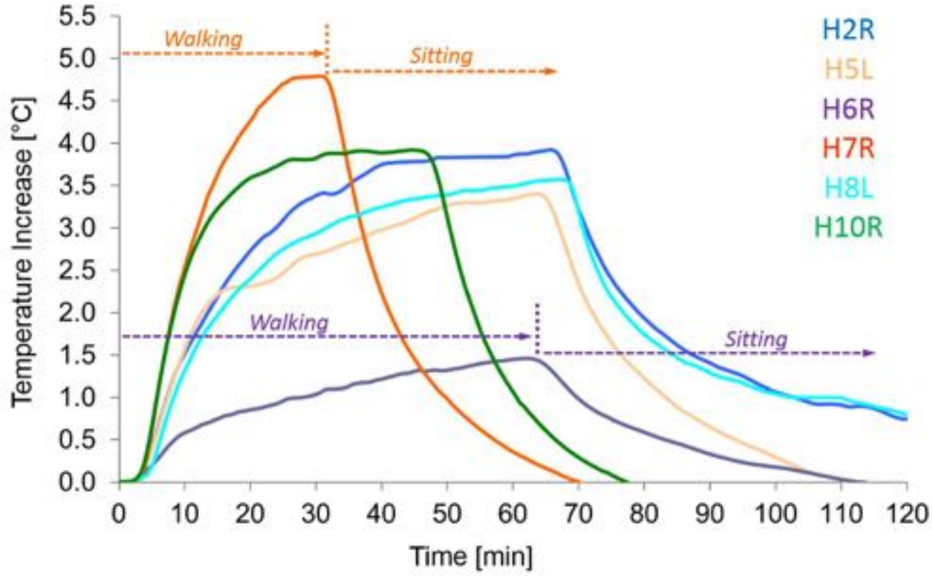

Figure 2: *In vivo* measured friction-induced temperature increase during level walking

Figure 2

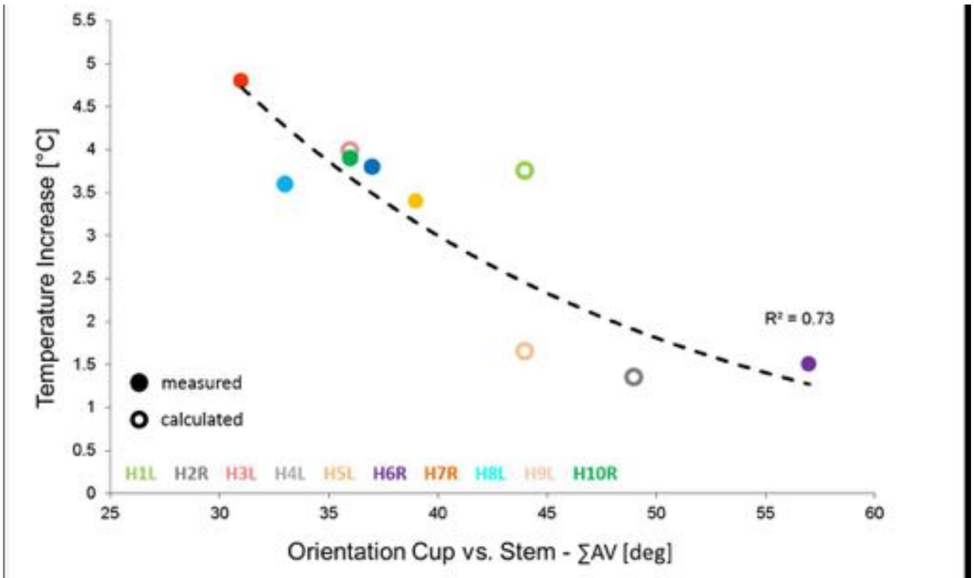

Figure 3: Correlation of the in-vivo temperature increase and implant orientation

Figure 3

#5561

Hip Capsule Biomechanics After Arthroplasty - the Effect of Approach, Implant and Surgical Repair

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Background

The hip's capsular ligaments (CL) passively restrain extreme range of motion (ROM) by wrapping around the native femoral head/neck, and protect against impingement and instability. We compared how CL function was affected by device (hip resurfacing arthroplasty, native head size, HRA; dual mobility total hip arthroplasty, near-native head size, DM-THA; and conventional THA, 32mm head size, C-THA), and surgical approach (anterior and posterior capsulotomy), with and without CL surgical-repair. We hypothesized that CL function would only be preserved when native head-size (HRA/DM-THA) was restored.

Methods

Sixteen paired fresh-frozen male cadaveric hips with no degenerative change were skeletonised, retaining the hip capsule. CL function was quantified by measuring ROM on a dual-axis servo-hydraulic testing machine with a load-cell. Hips underwent controlled internally (IR) and externally rotating (ER) in six functional positions, ranging from full extension with abduction to full flexion with adduction (squatting). Native ROM was compared to ROM after posterior capsulotomy (right hips) and anterior capsulotomy (left hips), and then after HRA, DM-THA and C-THA implants, before and after surgical CL repair.

Results

Independent of approach, ROM increased most following C-THA, then DM-THA, then HRA, indicating later engagement of the capsule and reduced biomechanical function with smaller head-size. Independent of implant, maximal increases in ROM were with internal rotation and flexed positions after posterior capsulotomy; and with internal rotation and extended positions after anterior capsulotomy.

After posterior capsulotomy, dislocations also occurred in squatting for the HRA, DM-THA and C-THA. CL-repair following HRA restored ROM to the native hip (max 8°) and prevented dislocation. CL-repair following DM-THA reduced ROM hypermobility in flexed positions only (max 36°) and prevented dislocation, indicating some restoration of CL function. CL-repair following C-THA did not reduce ROM or prevent dislocation.

After anterior capsulotomy, CL repair following HRA restored ROM to native (max 10°). DM-THA and repair reduced ROM hypermobility (max 42°). C-THA and repair did not reduce ROM.

Discussion

Increased ROM in flexed positions after posterior capsulotomy, and extended positions after anterior capsulotomy, corresponded to disruption of the iliofemoral and ischiofemoral ligament, respectively. For HRA and repair, native anatomy was preserved and CL function was restored. For DM-THA with repair, CL function depended on the movement of the mobile-bearing, with increased ROM in positions when ligaments could not wrap around head/neck. For C-THA, the reduced head-size resulted in inferior capsular mechanics in all positions as the CL remained slack, irrespective of repair.

Relevance

Preserving capsular ligament function may protect against instability following arthroplasty. This study demonstrated that with repair, choosing implants with native head-size may have a greater affect than surgical approach on ligament function in the early postoperative period.

#5724

Determinants of Total Hip Prostheses Stability-Related Success: The Role of Load-Bearing Surfaces Materials on Hip Capsule Thickness

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Introduction

Recent studies about hip stability after total hip arthroplasties (THA) concerned differences regarding bearings: ceramic on ceramic (CoC) presenting less dislocations on the long term compared to metal or ceramic on polyethylene. The hypothesis is a difference in the healing process of periarticular tissues, with a stronger fibrous tissue for the first one, and more foreign body reaction, joint effusion with the others.

Material and method

MRI Imaging of the pelvis showing both hips using novel Multi Acquisition Variable Resonance Image Combination(MAVRIC program) for metal artefacts suppression, were performed in 16 patients (median age 52 years old). Twenty nine hips were imaged. Thirteen hips had CoC bearings, 3 of which were impacted cementless bulky ceramic implant, and 10 had a metal back. Eleven hips had CoP bearings, 4 of which were cemented, 5 hips were native not operated. Measurements were conducted blindly for the material by two different observers at two different times.

Results

It was generally easy to identify the capsule and measure its thickness. Native capsules showed a mean thickness of 6.6mm. For CoC bearings, capsule thickness ranged from 7mm to 9.6 mm with a mean thickness of 8mm. For CoP bearings, capsule thickness ranged from 3mm to 8.4mm, with a mean thickness of 6.1mm. Neocapsule appeared clearly in all COC bearings observed, while for CoP, sometimes it was less dense with fatty aspect, 3 hips out of 7 having a very thin capsule under 4mm. Differences were highly significant ($p<0,0001$). These measurements were performed in four different parts , these differences remained significant in superior , anterior and posterior portions of the capsule , but not in the inferior part.

Conclusion and Discussion

It is possible to observe and quantify new capsule after THR and measure differences concerning capsule thickness; these differences where highly significant with thiscker capsules for Coc bearings couple compared either to ceramic or metal agaisnct polyethylene or compared to native non operated hips. Even if thicker capsule does not mean stronger , these differences might explain better long term stability in vivo observed with Coc.

Discussion remain about the reason for these findings; we suppose that this is related to the well tolerad material produced by coc with less inflammation , compared to the development of foreign body reaction with any bearings including polyethylene. Further questions remained and might be explored in the future.

Comparing the Deformation in the Cup of a Novel Ceramic Hip Resurfacing to a Metal Standard After Implantation in a Cadaveric Model

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INTRODUCTION

The cup component of modern resurfacing systems are often coated creating a cementless press-fit fixation in the acetabulum based on surgical under-reaming, also enabling osseoconduction/integration. Due to the higher density of cortical bone along the antero-superior and postero-inferior regions of the acetabulum, the greatest forces occur between the anterior and posterior columns of the pelvis. This produces pinching of the implant that can result in deformation of the cup. Metal shell/modularpress-fit acetabular cups are susceptible to substantial deformation immediately after implantation. This deformation may affect the lubrication, producing point loading and high friction torques between the head and the cup that increase wear and may lead to head clamping and subsequent cup loosening. We sought to test a novel ceramic on ceramic (CoC) hip resurfacing system that should allay any concerns with the Adverse Reaction to Metal Debris associated with metal on metal (MoM) resurfacing devices.

AIM

We sought to quantify the deformation of a novel CoC hip-resurfacing cup after implantation, using a standard surgical technique in a cadaveric model, and compare to the MoM standard. We also assessed if the design clearances proposed for this CoC hip resurfacing implant are compatible with the measured deformations, allowing for an adequate motion of the joint.

METHODS

The pelvis from four fresh frozen cadavers were placed into the lateral position. One surgeon with extensive experience in hip resurfacing surgery (JH) prepared all the pelvises for implantation using a posterior approach to the joint and sequential reaming of the acetabulum to 1mm below the implant outer diameter.

The acetabulum components were then impacted into the prepared pelvis. We used four ceramic and four metal implants of equal and varying size. (2 x (40/46mm, 44/50mm, 50/56mm, 52/58mm)).

The acetabulum cup bearing surface diameter and deformation was measured using a GOM-ATOS optical high precision 3D scanner. 3-Dimensional measurements were taken pre-implantation, immediately after and at 30 minutes following implantation. Two techniques were used to analyse the 3D images: by maximum inscribed diameter and by radial segments. These were compared to the known articulating surface clearance values (Fig. 1).

RESULTS

The diameter of the cups in both metal and ceramic systems was reduced after implantation when analysing by maximum inscribed diameter (Fig. 2) and by radial segments (Fig. 3). This deformation was maintained at 30 minutes. We can infer there is no significant bone stress relaxation effect following implantation.

On ceramic cups, the deformation was larger in larger sizes. However, the 44/50 (the second smallest cup) deformed the least. Despite this, the difference in deformation between these two sizes is minimal. The deformation of sizes 50/56 and 52/58 was equivalent. For the metal cups, there was not a clear correlation between the cup size and the deformation. The largest cup size had the same deformation as the smallest size.

CONCLUSIONS

The deformation following implantation of the cup component in a ceramic acetabulum resurfacing behave similarly to a metal implant. Cup deformation measured after implantation is minimal when compared to the minimum design clearance in both systems.

Figures

Cup size	ReCerf cups deformation after impaction (µm)	ReCerf Minimum clearance (µm)	ADEPT cups deformation after impaction (µm)	ADEPT Minimum clearance (µm)
40/46	19	65	33	134
44/50	15	80	27	149
50/56	27	80	44	172
52/58	30	90	32	180

Table 1 . Diameter reduction against minimum design clearances.

Figure 1

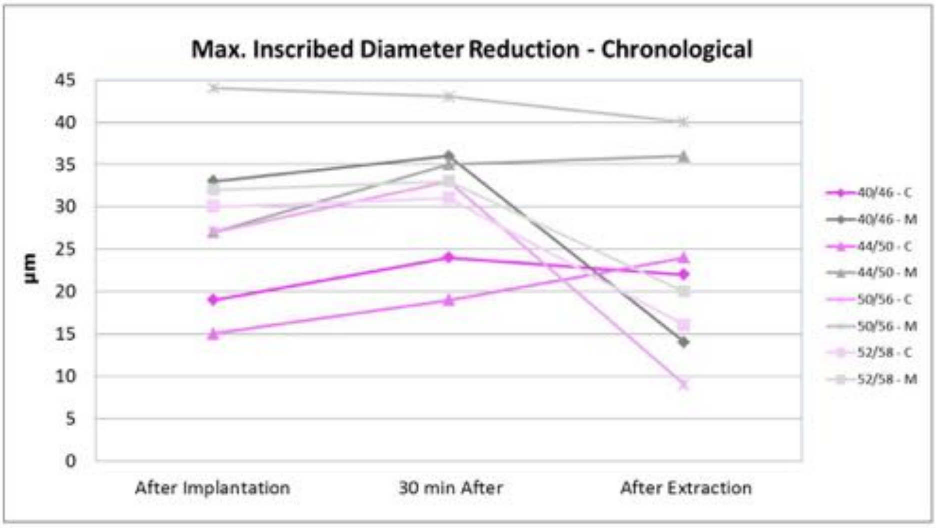

Figure 2. Diameter reduction measured for all the tested cups in chronological order. Pink lines represent ceramic cups and grey lines the metal cups.

Figure 2

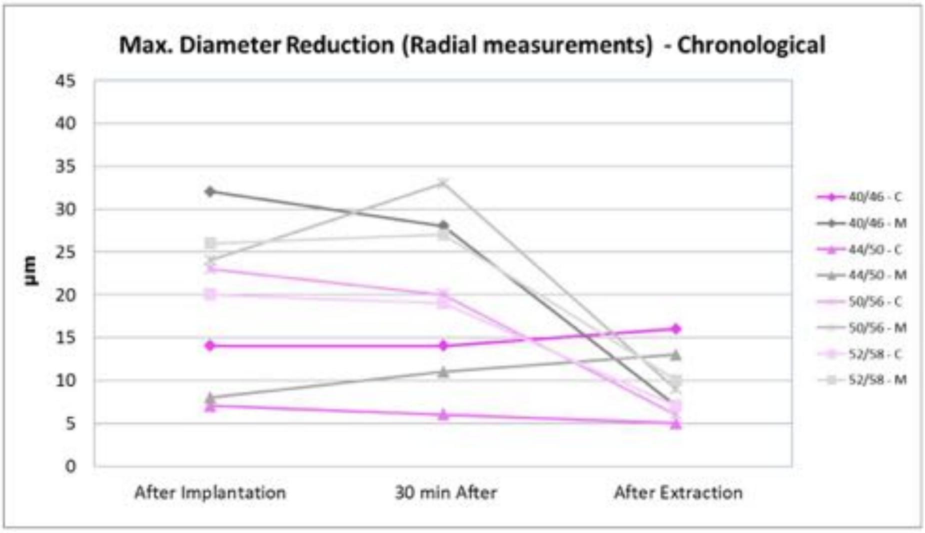

Figure 3 . Diameter reduction measured for all the tested cups in chronological order – Radial segments method. Pink lines represent ceramic cups and grey lines the metal cups.

Figure 3

#5615

What's Behind Acetabular Impingement: An in Vitro Study

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Introduction

Recurrent dislocation due to femoral stem impingement with the acetabular liner is historically one of the main cause of failure in total hip arthroplasty. The occurrence of in-vivo impingement is relate to misalignment or extreme hip range of motion and may lead to acetabular liner damage and create polyethylene wear. The aim of this study is to assess by finite element analysis the effect of implant design parameters on impingement and reproduce in-vitro mechanical test following ASTM F2582-14 on the worst-case combination (Figure 1).

Materials and methods

The complexity under the definition of the worst case system for impingement is due to the great number of components analyzed and variables involved. According to ASTM F2582-14 the influence of different combinations of acetabular cup, polyethylene liner, femoral head and stem is evaluated with a complete numerical and geometrical analysis carried out component by component with a non-liner FE analysis performed in ANSYS 17.2 environment. Materials are described with an elastic linear behavior, since yield point should be avoided, with the following material properties: Ti6Al4V (elastic modulus E=114 GPa, Poisson's ratio ν=0,33), CoCrMo (E=210 GPa, ν=0,3), M30NW (E=181 GPa, ν=0,3), UHMWPE (E=0,78 GPa, ν=0,4). Significant parameters such as acetabular cup, head diameter, polyethylene liner thickness, head offset and femoral stem profile are progressively compared in the FE post processing, allowing to gradually exclude the configurations which lead to a less severe loading of the polyethylene liner. Worst-case combination is defined comparing the results of numerical investigation in terms of compressive stress (MPS_{COM}) and maximum contact pressure (p_{MAX}) at the impingement contact region, together with the stress (MPS_{MIN}) at the minimum liner thickness region. Impingement test was run on three samples of the worst case combination i.e. Delta TT Cup #54, UHMWPE X-LIMA Neutral Liner, CoCrMo Femoral Head 36 and C2 Standard #01 (LimaCorporate, Italy) according to ASTM F2582-14. Artificial aging on polyethylene components was performed according ASTM F2003.

Results

Numerical results shows the higher stress induced in the polyethylene is achieved with the thinnest polyethylene rim liner, the most deformable cup and the higher curvature difference between liner and stem neck in the size range (Figure 2). Over a 1,0 MC in vitro impingement test, the gravimetric wear rate was 4,6±1,3 mg/MC and the average penetration rate was 1,1±0,1 mm/MC. The average penetration rate calculated from 0 to 0,2 MC and from 0,2 to 1,0 MC was 6,2±0,1 mm/MC and 0,3±0,1 mm/MC respectively.

Discussion

Impingement test was performed on Delta TT acetabular cup coupled with X-LIMA polyethylene liner and C2 femoral stem, both with ODEP 5A*, showing no rim fracture or locking mechanism failure. Additionally, no femoral head dislocation or liner dissociation from the shell was observed in any test samples. Lastly, no metal impingement was noted during the course of the test.

References

ASTM F2582-14 – Standard Test Method for Impingement of Acetabular Prostheses.

Figures

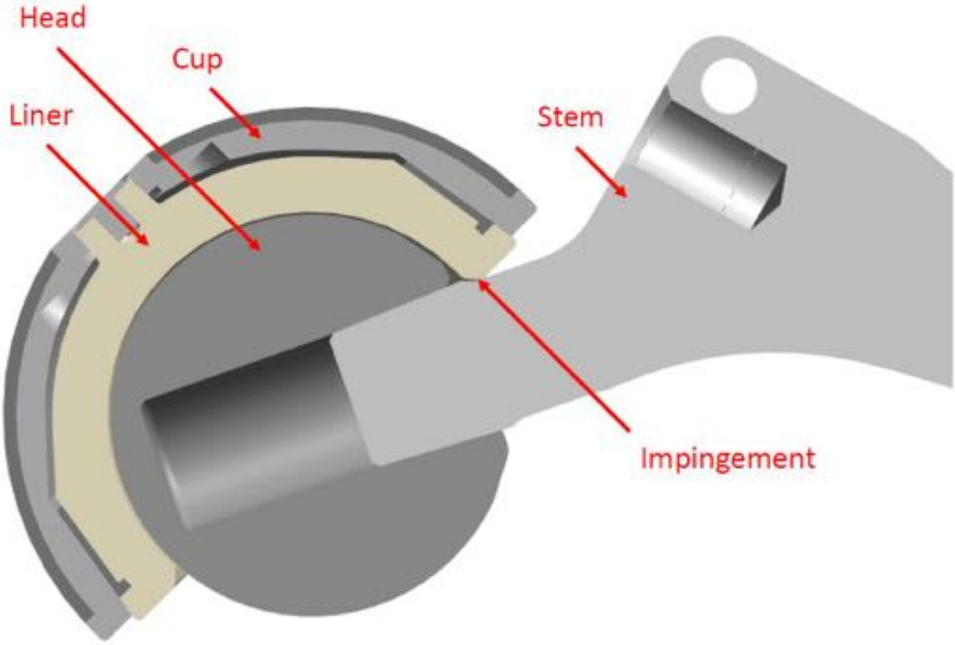

Figure 1

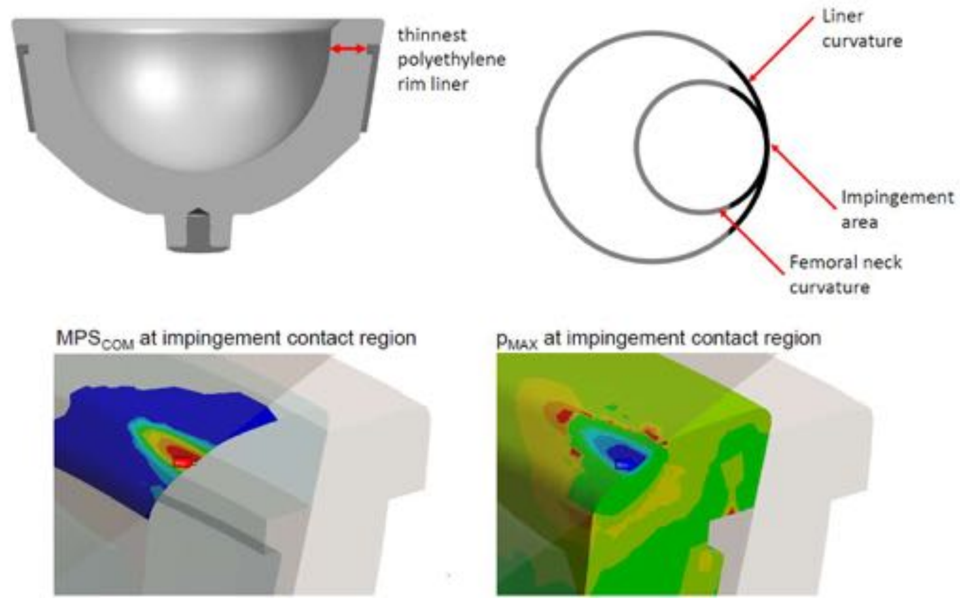

Figure 2

#5826

Lumbar Spine Degeneration and Flatback Deformity Alter Sitting-Standing Spinopelvic Mechanics - a Detailed Analysis of Segmental Spinal Alignment Change

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INTRODUCTION: Standing spinal alignment has been the center of focus recently, particularly in the setting of adult spinal deformity. Humans spend approximately half of their waking life in a seated position. While lumbopelvic sagittal alignment has been shown to adapt from standing to sitting posture, segmental vertebral alignment of the entire spine is not yet fully understood, nor are the effects of DEGEN or DEFORMITY. Segmental spinal alignment between sitting and standing, and the effects of degeneration and deformity were analyzed.

METHODS: Segmental spinal alignment and lumbopelvic alignment (pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), PI-LL, sacral slope) were analyzed. Lumbar spines were classified as NORMAL, DEGEN (at least one level of disc height loss >50%, facet arthropathy, or spondylolisthesis), or DEFORMITY (PI-LL mismatch>10°). Exclusion criteria included lumbar fusion/ankylosis, hip arthroplasty, and transitional lumbosacral anatomy. Independent samples t-tests analyzed lumbopelvic and segmental alignment between sitting and standing within groups. ANOVA assessed these differences between spine pathology groups.

RESULTS: There were 183 NORMAL, 216 DEGEN and 92 DEFORMITY patients with significant differences in age, gender, and hip OA grades. After propensity matching for these factors, there were 56 patients in each group (age 63±14, 58% female) [Fig. 1]. Significant differences were noted between spinal pathology groups with regard to changes from standing to sitting alignment with regard to NORMAL vs DEGEN vs DEFORMITY groups in PT (13.93° vs -11.98° vs -7.95°; p=0.024), LL (21.91° vs 17.45° vs 13.23°; p=0.002), PI-LL (-22.32° vs -17.28° vs -13.18°; p<0.001), SVA (-48.99° vs -29.98° vs -32.12°; p=0.002), and TPA(-16.35° vs -12.69° vs -9.64; p=0.001). TK (-2.08° vs -2.78° vs -2.00°, p=0.943) and CL (-3.84° vs -4.14° vs -3.57°, p=0.621) were not significantly different across spinal pathology groups [Fig. 2].

NORMAL patients had overall greater mobility in the lower lumbar spine from standing to sitting compared to DEGEN and DEFORMITY patients. L4-L5 (7.50° vs 5.23° vs 4.74°, p=0.012) and L5-S1 (6.96° vs 5.28° and 3.69°, p=0.027). There were no significant differences in change in alignment from standing to sitting at the upper lumbar levels or lower thoracic levels between the three groups [Fig. 3].

CONCLUSION: The lower lumbar spine provides the greatest sitting to standing change in lumbopelvic alignment in normal patients. Degeneration and deformity of the spine significantly reduces the mobility of the lower lumbar spine and PT. With lumbar spine degeneration and flatback deformity, relatively more alignment change occurs at the upper lumbar spine and thoracolumbar junction.

Figures

Figure 1. Patient demographics for all patients (unmatched) and with propensity score matching controlling for age, BMI, and hip OA grade (matched).

Characteristic	Total	Normal	Degenerative	Flatback	*p-value*
	Unmatched				
Cases	491	183	216	92	
Age, years (SD)	60.94 (±13.49)	52.29 (±13.54)	65.71 (±9.68)	66.33 (±12.79)	<0.001
BMI, kg/m^2 (SD)	27.72 (±5.77)	26.91 (±5.11)	27.86 (±5.85)	29.01 (±6.59)	0.018
Sex,					
% Female	61.30%	64.70%	61.80%	53.80%	0.229
% Male	38.70%	35.30%	38.20%	46.20%	
Hip OA grade (SD)	2.22 (±1.24)	1.79 (±1.19)	2.45 (±1.19)	2.49 (±1.21)	<0.001
	Matched				
Cases	171	57	57	57	
Age, years (SD)	61.76 (±11.42)	61.25 (±11.86)	62.55 (±9.96)	61.49 (±12.46)	0.812
BMI, kg/m^2 (SD)	28.10 (±5.84)	28.41 (±5.61)	27.51 (±5.14)	28.38 (±6.71)	0.646
Sex					
% Female	58.00%	58.90%	64.30%	50.90%	0.347
% Male	42.00%	41.1%	35.7%	49.10%	
Hip OA grade (SD)	2.26 (±1.17)	2.28 (±1.00)	2.30 (±1.32)	2.21 (±1.19)	0.915

BMI: body mass index; OA: osteoarthritis; SD: standard deviation

Figure 1

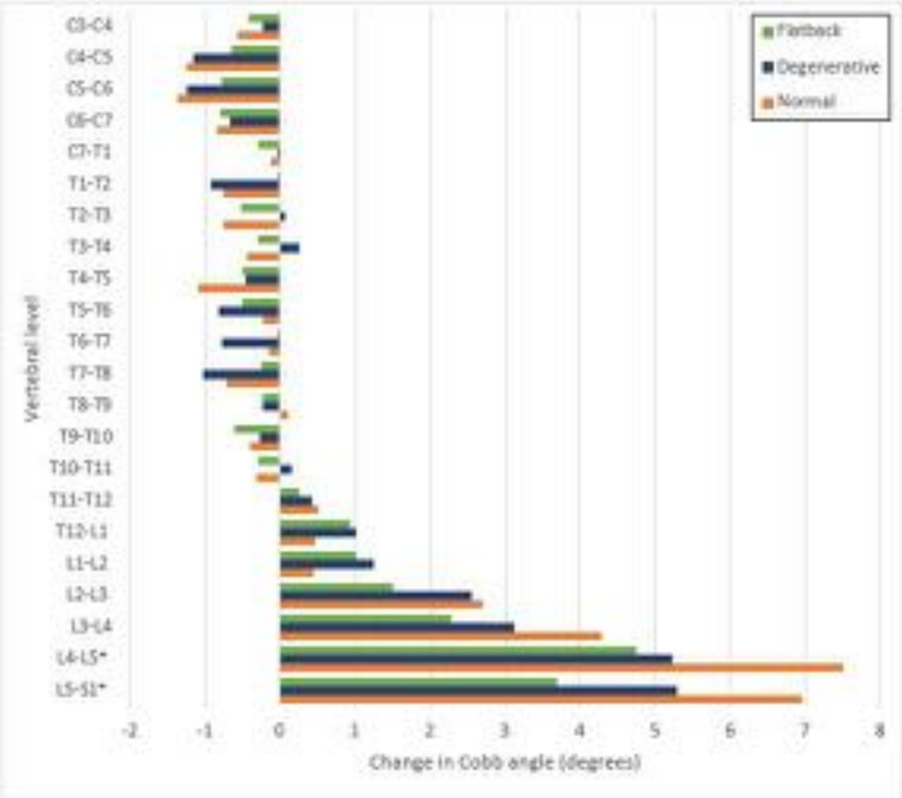
Figure 2. Change in sagittal parameters during the transition from sitting to standing between normal, degenerative, and lumbar flatback groups.

	PT*	PI	PI-LL**	LL**	TK	TS-CL	CL	SVA**	TPA**
Normal	-13.93	-0.42	-22.32	21.91	-2.08	-0.78	-3.84	-48.99	-16.35
Degenerative	-11.98	0.17	-17.28	17.45	-2.78	1.35	-4.14	-29.98	-12.69
Flatback	-7.95	0.05	-13.18	13.23	-2.00	0.37	-3.57	-32.12	-9.84

* Indicates significant values with p < .05; ** indicates significant values with p < .01; Abbreviations: CL: cervical lordosis; LL: lumbar lordosis; PI: pelvic incidence; PI-LL: mismatch between pelvic incidence and lumbar lordosis; PT: pelvic tilt; SVA: sagittal vertical axis; TK: T4-T12 thoracic kyphosis; TPA: T1 pelvic angle. TS-CL: mismatch between T1 slope and cervical lordosis.

Figure 2

Figure 3. Change in Cobb angle at each vertebral level with transition from sitting to standing between normal, degenerative, and lumbar flatback groups.



* Indicates significant values with p < .05.

Figure 3

#5829

Statistical Shape Model of the Pelvis to Drive Secondary Initial Acetabular Fixation Design

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The “scratch fit” of modern acetabular cup implants with highly porous coatings is often adequate for initial fixation in primary total hip arthroplasty. Depending on bone quality, the surgical protocol generally involves reaming the acetabulum either line-to-line or 1 millimeter under compared to the final cup size. Initial fixation must limit micromotion to acceptable levels to facilitate osseointegration and long term cup stability. Secondary initial fixation can be required in cases with poor bone quality or bone loss and is commonly achieved with bone screws and a cup implant with multiple screw holes. To provide maximum secondary initial fixation, the cup screw holes should be positioned to allow access to the limited region of thick pelvic bone. A study of the pelvis was performed to map pelvis thickness to optimize secondary initial fixation design.

Through a partnership with Materialise, a statistical shape model of the pelvis was created utilizing 80 CT scans (36 female, 44 male). To limit the effect of variation outside the area of cup implant fixation, the shape model includes only the inferior pelvis (cut off at the greater sciatic notch and above the anterior inferior iliac spine).

A virtual implantation protocol was developed which creates instances of the shape model that accurately simulate the intraoperative preparation of the acetabulum to accept the cup implant. First a sphere is best fit to the native acetabulum and is rounded to the nearest whole millimeter. The diameter of the best fit sphere is offset by 1mm to simulate bone removal during the spherical reaming step. The sphere is positioned medially and superiorly such that it is tangent to the teardrop and removes 2mm of superior acetabulum. The sphere is used to perform a Boolean subtraction from the shape model to create a prepared pelvis shape model. An example is shown in Figure 1.

The Materialise 3-Matic software was used to perform a thickness analysis of the prepared shape models. The results are displayed as a color “heat map” where green represents thin bone and red is thick bone. The analysis finds there is a limited arc of thick bone that begins superiorly and extends posterior-inferior that accounts for only about 15% of total prepared surface area. The superior location facilitates the placement of a long bone screw up the iliac column and the posterior-inferior region facilitates the placement of additional posterior screws. Figure 2 illustrates the superior to posterior-inferior arch of thick bone and Figure 3 illustrates the same model with a different thickness scale that isolates the thickest bone in the superior location.

The shape model development, virtual implantation protocol, and heat map thickness analysis provide a design tool to ensure optimal placement of bone screws in a cup implant to access the limited thick arc of pelvic bone and ensure initial implant fixation.

Figures

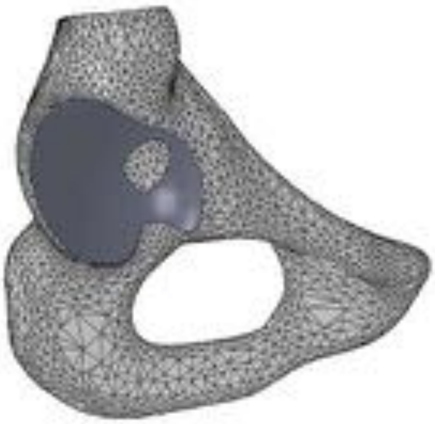

Figure 1

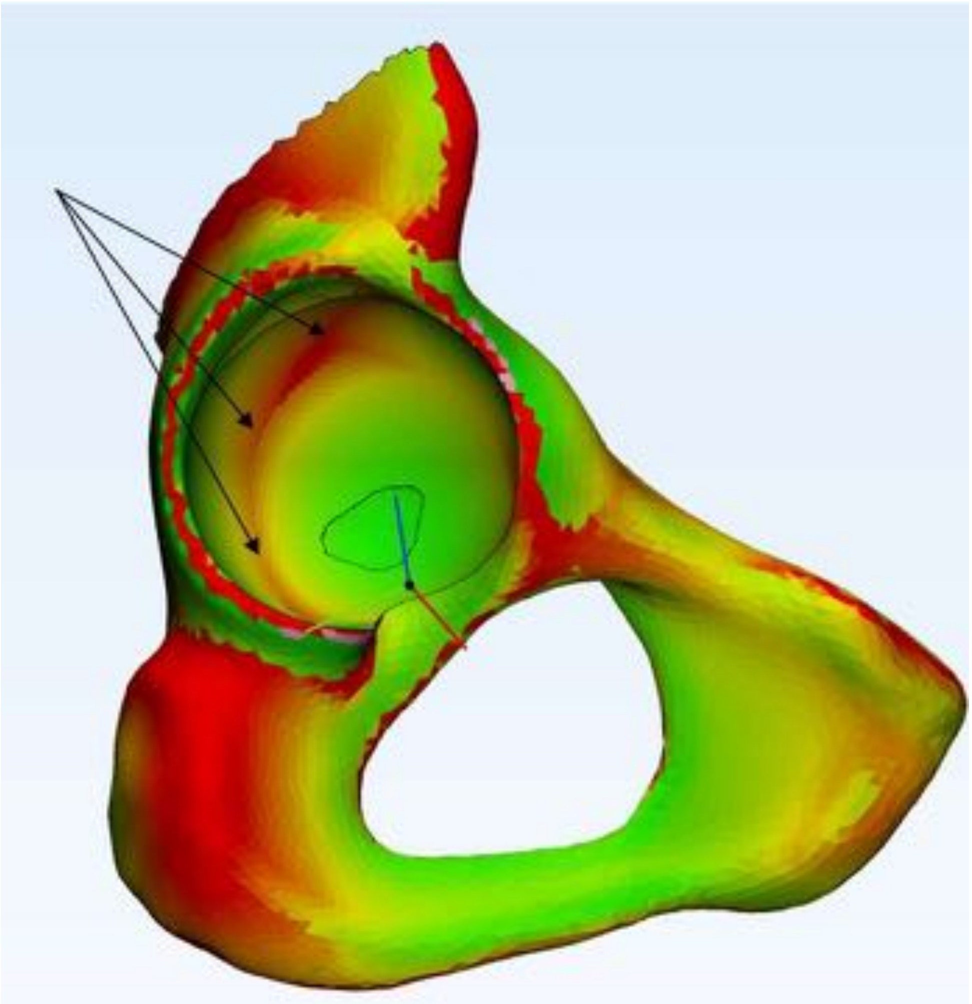

Figure 2

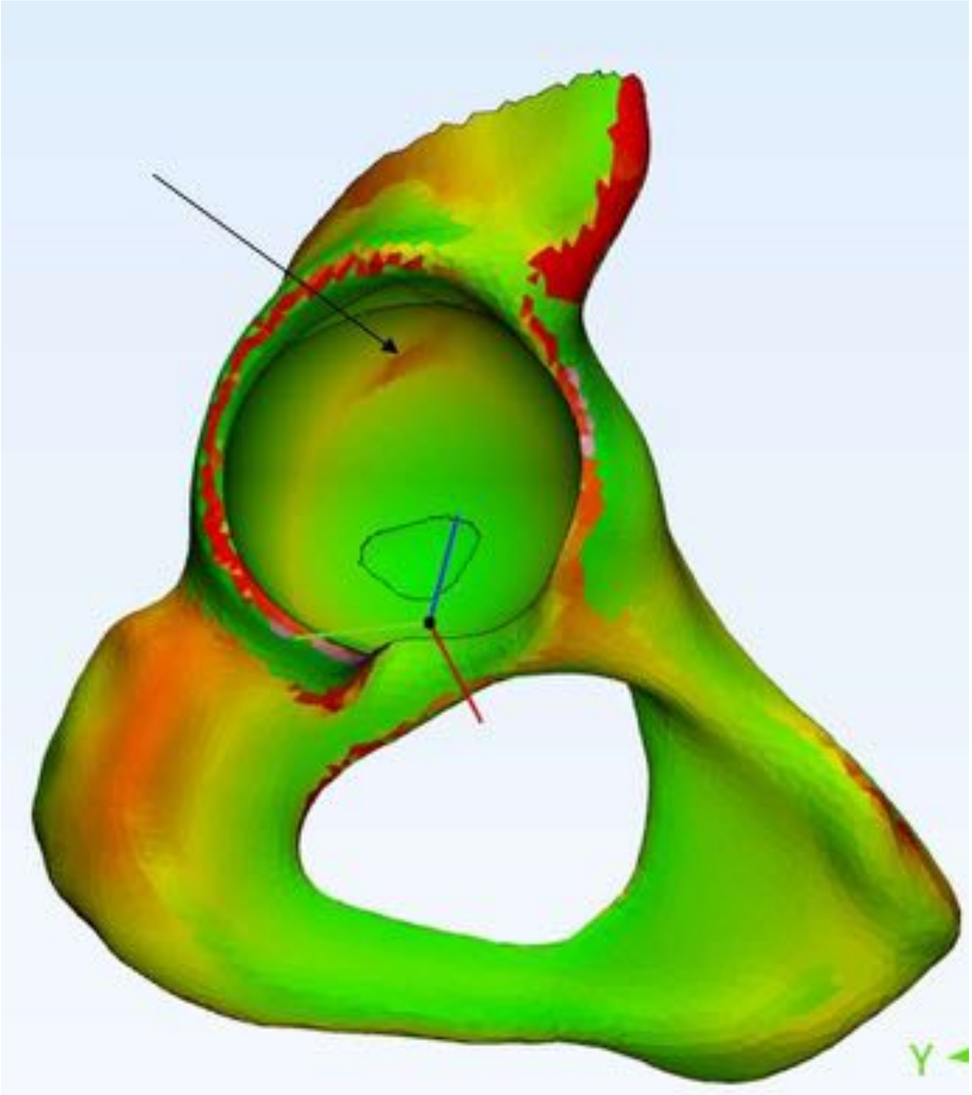

Figure 3

#5993

Does a Close to Native Anatomy Prosthetic Hip Restoration Improves Functional Scores and Gait?

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Background: The aim of our study aims to assess, in a group of patients with a well-functioning hip replacement, the functional influence (gait and functional scores) of restoring a close to physiologic hip biomechanics and to answer the following questions: 1) Does a better anatomical hip restoration influences functional outcomes after hip replacement? And 2) Does patients implanted with a HR perform better than the one implanted with a THR?

Methods: Fifty-two patients with successful prosthetic hip (40 THRs and 12 HRs) and having undertaken a functional assessment (gait analysis and Oxford Hip Score) at a mean follow-up of 14 months were retrospectively reviewed. The quality of the biomechanical restoration by the hip replacement was assessed on X-ray by comparison with the healthy contralateral hip.

Results: We found no statistically significant correlation between radiographic measurements and gait parameters or functional scores. HR patients tended to have a more symmetric gait, less influenced by speed and ramp inclination changes, but this didn’t reach statistical significance.

Discussion/conclusion: Slight variation regarding the quality of the anatomical restoration (hip anatomical parameters measured in an AP pelvis radiograph) when performing hip replacement had negligible influence on the patients functional performance. Similarly, HR had little functional benefit compared to well-functioning and well reconstructed THR. The clinical benefits of preserving the femoral neck and the individual (patient-specific) hip anatomy and biomechanics need to be further studied.

#5628

The Fate of Sagittal Aligment and Femoral Filling in Tapered Cementless Stems in Total Hip Arthroplasty

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Background: Aseptic loosening is rare with most cementless tapered stems in primary total hip arthroplasty (THA), however different factors can modify results. We ask if the shape and technique of three current different femoral components affects the clinical and radiological outcome after a minimum follow-up of ten years.
Methods: 889 cementless tapered stems implanted from 1999 to 2007 were prospectively followed. Group 1 (273 hips) shared a conical shape and a porous-coated surface, group 2 (286 hips) a conical splined shape and group 3 (330 hips) a rectangular stem. Clinical outcome and anteroposterior and sagittal radiographic analysis were compared. Femoral type, stem position, femoral canal filling at three levels and the possible appearance of loosening and bone remodelling changes were assessed.
Results: No thigh pain was reported in unrevised patients. Mean Harris Hip score was lower for patients in group 3 for pain and function at 6 months, two years and at latest follow-up. The survival rate of not having revision of the stem for any cause was 98.5% (95% CI 98.8-100) for group 1 at 12 years, 99.3 % ((95% Confidence Intervals (CI) 97.9-100) for group 2 at 16 years and 97.7% (95% (CI) 94-100) for group 3 at 14 years, and (log rank= 0.109). Thirteen stems from the latter were revised for aseptic loosening. No revision for aseptic loosening was found in the other designs. After controlling all confounding factors, the risk for aseptic loosening in group 3 was related to a lower femoral canal filling (p=0.039, Hazard Ratio (HR):0.918, 95% Confidence Interval (CI):0.846-0.996) and a stem position outside neutral limits in the sagittal alignment (p=0.048, HR:3.581, 95% CI:1.010-12.696).
Conclusions: Conical tapered cementless stems are more reliable than rectangular straight designs in primary THA after ten years

#5992

Poor Relationship Between Femorotibial and Trochlear Anatomic Parameters

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Background: The kinematic alignment (KA) technique for total knee arthroplasty (TKA) is an emerging implant positioning philosophy that aims to preserve constitutional knee anatomy in order to improve knee kinematics, and hence clinical outcomes, after total replacement. The KA technique is proven to be safe with good efficacy, while not being inferior to mechanically aligned (MA) total knee arthroplasty (TKA) at early-term follow-up. At present, the KA technique aims to reconstruct native femorotibial (FT) joint alignment, however there is still insufficient consideration towards the highly inter-individual trochlear anatomy variability. Poor trochlear restoration may compromise clinical outcomes of KA TKAs, and explain the occurence of patellofemoral (PF) related complications after KA TKAs. As new femoral component designs may soon account for KA technique, our study aimed at assessing the anatomical relationship between the native trochlea (alignment, length, and stiffness) and other FT anatomical parameters. The null hypothesis is that there is no relationship between trochlea and FT anatomical parameters.

Method: Fifty-eight preoperative CT scans of low-grade knee arthritic patients were segmented to create 3D bone models, including complete femoral head, entire knee and ankle. The FT and the PF anatomical parameters were measured using in-house software. Values were compared between different groups of lower limb and FT joint line (JL) alignment, and correlations between FT and PF anatomical parameters were assessed.

Results: We didn’t find any significant correlation between groove alignment (frontal and axial) or groove radius and either the Hip-Knee-Ankle (HKA), or the Lateral Distal Femoral (LDFA), or the Medial Proximal Tibial (MPTA), or the FTJL-Mechanical Axis (FTJLMAA) Angles. When looking at the correlation within sub-groups of limb or JL alignments, we only found a strong positive correlation ($r=0.464$, $p=0.022$) in the varus lower limb (HKA ≤ 180°) sub-group between groove frontal alignment and LDFA. The groove alignment (frontal and axial) and groove radius was not significantly different between the different groups of lower limb or joint line alignments. However, we found a larger proximal lateral facet height (at 0°), and lateral (at 0° and 20°) and medial (at 0°) jumping distance when the tibial plateau was in valgus (MPTA > 90°).

Discussion/conclusion: Our study shows that the determination of several limb, knee, and JL parameters is of poor value to predict individual trochlea anatomy. This raises the issue of how to improve femoral component design in order to achieve individualised FT and PF anatomical restoration with KA TKA.

#5685

Robotic Evaluation of the Patellofemoral Envelope of Motion

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Introduction

In knee biomechanics the concept of the envelope of motion (EOM) [Blankevoort et al, JBiomech 1988] has proven to be a powerful method to characterize joint mechanics and the effect of surgical interventions. It is furthermore indispensable for numerical model validation. While commonly used for tibiofemoral kinematics, there is very little report of applying the concept to patellofemoral kinematics. EOM measurements require precise and reproducible displacement and load control in all degrees of freedom (DOF), which robotic testing has proven to provide. The objectives of this study were therefore to (1) develop a robotic method to assess patellofemoral EOM as a function of tibiofemoral EOM, (2) compare resulting patellofemoral kinematics to published data, and (3) determine which DOFs in the tibiofemoral EOM mostly account for the patellofemoral EOM.

Material and Methods

The developed robotic (KUKA KR140 comp) method was evaluated using 8 post-mortem human leg specimens of both genders (age: 55±11 years, BMI: 23±5). Firstly, tibiofemoral neutral flexion was established as well as the EOM by applying anterior-posterior (±100 N), medial-lateral (±100 N), internal-external (±4 Nm) and varus-valgus (±12 Nm) loads under low compression (44 N) at 7 flexion angles. Secondly, patellofemoral flexion kinematics and EOM were measured during a robotic playback of the previously established tibiofemoral kinematics. During these measurements, the quadriceps tendon was loaded with a hanging weight (20 kg) via a pulley system directing the force to the anterior superior iliac spine. Kinematics were tracked optically (OptiTrack) and registered to CT scans using co-scanned aluminium cylinders and beads embedded in the patella.

The overall patellofemoral EOM was calculated as the extent of patellar motion observed during manipulating the tibia inside the tibiofemoral EOM in all DOFs. Additionally, patellofemoral EOMs were calculated for tibial manipulations along individual DOFs to analyse the importance of these DOFs.

Results

Figure 1 shows patellofemoral kinematics during knee flexion and the overall patellofemoral EOM. Trends and magnitudes of patella shift, tilt and rotation during flexion were similar to reported in-vivo measurements [Nha et al, JOR 2008]. Envelopes of patellar shift and tilt during internal-external tibiofemoral rotation closely resembled those reported for in-vitro results [Barink et al, KSSTA 2007] despite methodological differences.

Tibiofemoral internal-external and varus-valgus rotation had the largest effect on patellofemoral EOM (Figure 2). EOMs in patellar shift and tilt were dominated by internal-external rotation in early flexion and varus-valgus rotation in late flexion. The EOM in patellar rotation was dominated by tibiofemoral varus-valgus rotation throughout flexion (Figure 3). Manipulating the tibia in a combined internal-external and varus-valgus rotation envelope yielded the same patellofemoral EOM as the overall patellofemoral EOM (Figure 2).

Conclusion

This study has established a novel robotic method to assess the patellofemoral envelope of motion as a function of tibiofemoral EOM. Resulting patellofemoral kinematics resembled data reported in literature. It was furthermore shown that is sufficient to establish a combined internal-external and varus-valgus envelope of tibiofemoral motion as bases of the patellofemoral EOM, as including the anterior-posterior and medial-lateral tibiofemoral envelopes yielded no additional effect.

Figures

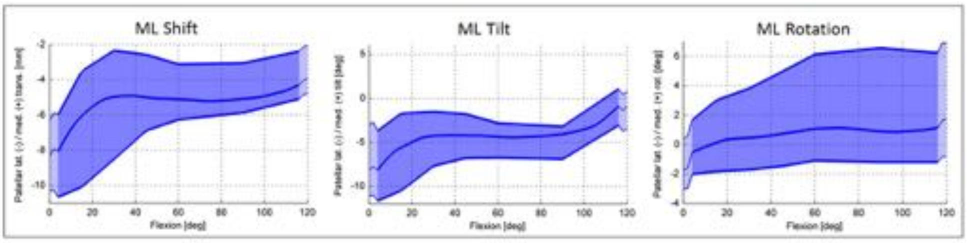

Figure 1: Average patellofemoral kinematics during knee flexion inside overall patellofemoral EOM.
The darker shade indicates the flexion range with data from all specimens.

Figure 1

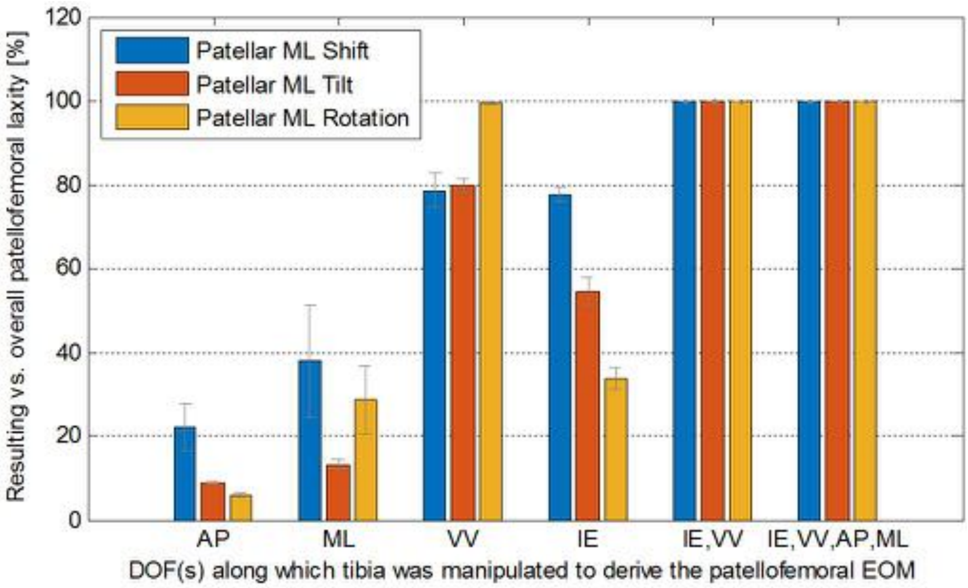

Figure 2: Effect of DOFs in the tibiofemoral EOM on the patellofemoral EOM.

Figure 2

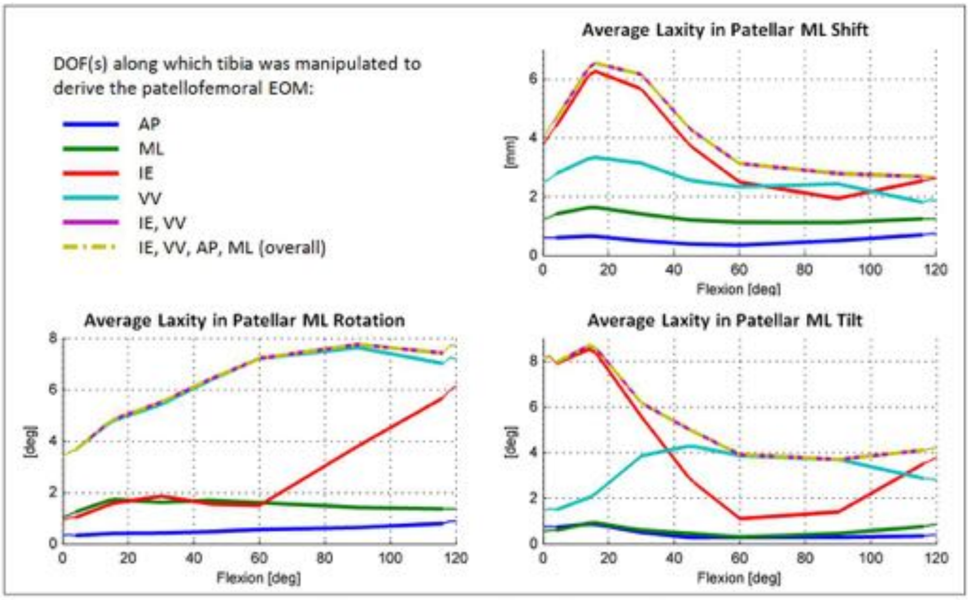

Figure 3: Laxity of patellofemoral EOM for different tibiofemoral EOMs.

Figure 3

#5907

Gait Analysis of Individuals With Isolated Posterior Cruciate Deficiency

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Background: The cruciate ligaments are important structures for biomechanical stability of the knee. For total knee arthroplasty (TKA), understanding of the exact function of the (PCL) and anterior (ACL) cruciate ligament during walking is important in the light of recent designs of bicruciate TKAs. However, studies evaluating in vivo function of the PCL during daily activities such as walking are scarce. We aimed to assess the role of the PCL during gait by measuring kinematics and kinetics of individuals with isolated PCL-deficiency and compare them with individuals with ACL-deficiency and healthy young adults.

Methods: Individuals with isolated, unilateral PCL deficiency (PCLD; n=9), isolated, unilateral ACL deficiency (n=10) and healthy young adults performed (n=10) 10 walk trials (5 for each leg) in which they walked over a force platform. Motion analysis (Vicon Motion Capture System) was used to calculate joint angles and internal moments around the knee, hip and ankle in the sagittal plane. Joint angles and moments of the injured knee (in PCLD and ACLD) or left knee (in HYA) were compared between groups at weight acceptance, mid-stance and push-off phases (see Fig. 1). Clinical assessment included passive knee laxity (Kneelax) for anterior (in 20-30° knee flexion) and posterior tibia translation (in 70-90° knee flexion) and Lysholm questionnaires.

Results: Lysholm scores were significantly lower in PCLD and ACLD individuals compared to HYA (p's ≤ .001). PCLD subjects had more passive anterior (p = .001) and posterior tibia translation (p = .041) compared to HYA, but no significant differences were found in both directions between ACLD and HYA (p's > .10). During gait, knee angles at weight acceptance, late stance and around toe-off were not significantly different between the PCLD and HYA, and between ACLD and HYA (all p's > .06). However, the knee extension moment during mid-stance was significantly lower in the PCLD group when compared to the HYA group (p = .001; Fig. 2). Interestingly, the knee moment in the PCLD group remained positive (i.e. extension moment) throughout the stance phase, whereas HYA and ACLD groups created a substantial flexion moment around the knee at this instant. We did not observe any significant differences in hip and ankle joint angles and moments between groups.

Discussion: We observed a difference in gait pattern in individuals with PCL deficiency compared to HYA, that was confined to an absence of knee flexion moments during the mid-stance phase. We hypothesize that this difference reflects a compensation strategy employed by individuals with PCL deficiency to avoid external knee (hyper)extension moments. Gait adaptations related to PCL deficiency might also have implications for design of total knee prosthesis and calls for careful evaluation of gait patterns after TKA

with a specific focus on the role of the PCL.

Figures

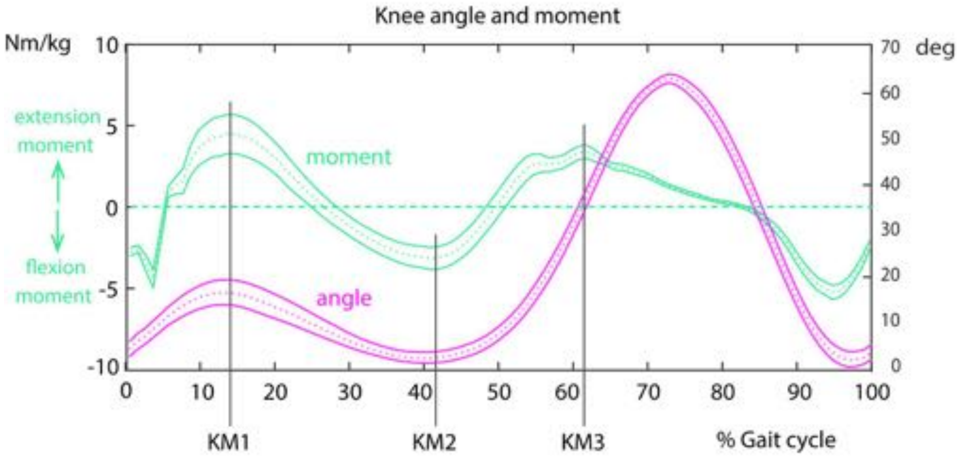

Figure 1. Sagittal knee angle (pink) and moments (green) of HYA during the gait cycle were normalized to the duration of the gait cycle. Maximal knee extension moment at weight acceptance (KM1), maximal flexion moment during mid-stance (KM2) and maximal extension moment around push-off (KM3) were identified. Moments and angles around knee, hip and ankle were also evaluated at these instants.

Figure 1

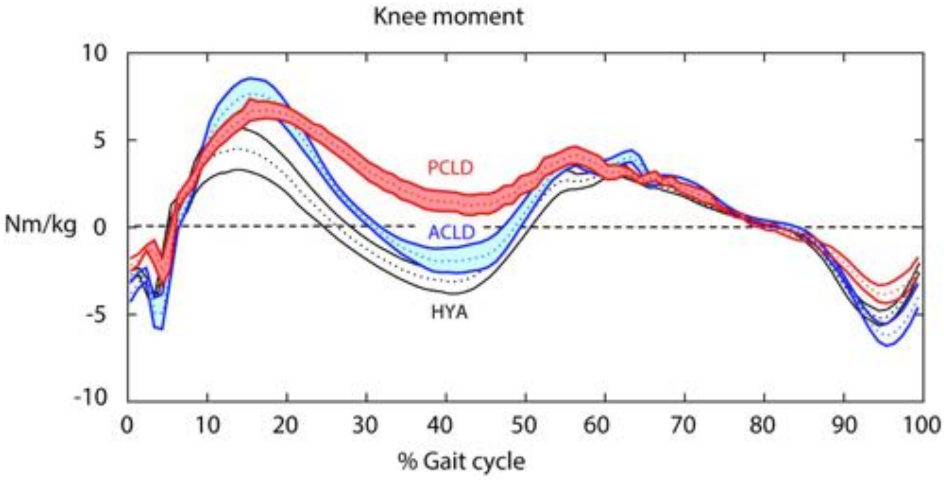

Figure 2. Mean ± SE of the sagittal knee moment during the gait cycle for PCLD (red), ACLD (blue) and HYA (black) were compared.

Figure 2

Can the Quality of Proximal Tibial Bone Be Predicted From Cortical Measurements Derived From Plain Radiograph?

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INTRODUCTION: The quality of bone within the proximal tibia and distal femur are key determinants of component fixation in total knee replacement (TKR). Although bone mineral density (BMD) may be measured by quantitative computed tomography (qCT) and dual-energy x-ray absorptiometry, these imaging modalities are not readily utilized for preoperative planning for joint replacement, primarily because of the associated costs and inconvenience. However, plain radiographs are used universally as part of the work up for these procedures, though previous studies have shown that these images are of limited value for estimating the quality of metaphyseal bone. In this study, we examine whether simple parameters derived from plain radiographs can be used to accurately predict the density of metaphyseal bone at the level of the proximal tibial osteotomy for use in preoperative planning for TKR.

METHODS: qCT scans were obtained from 48 cadaveric knee specimens (18 Male, 6 Female, Average age: 52±12 years, Average BMI: 25.84±5.14 kg/m^2). Each knee was scanned on top of standard bone phantoms (Mindways Software Inc, QCT Pro Model 3 CT Calibration Phantoms). Using image processing software (Mimics by Materialise NV), we measured: 1. Absolute BMDs of 3.5mm thick metaphyseal bone slices perpendicular to the canal axis, 10mm distal to the tibial medial plateau, and 2. Thicknesses of the medial, lateral, and posterior cortices 130mm distal to the joint line (Figure 1). Three parameters were derived from the cortical measurements as predictors of metaphyseal BMD: 1. Sum of the medial and lateral thicknesses (SUM), 2. Average of the thicknesses of the medial, lateral, and posterior cortices (AVG), and 3. Cortical bone index defined as the percentage of the mediolateral width of the diaphysis occupied by the cortices (CBI). Using the three parameters, bones were classified as Normal (SUM > 10mm, AVG > 7mm, CBI > 0.40), Osteopenic (10mm > SUM > 6mm, 7mm > AVG > 5mm, 0.40 > CBI > 0.25), or Osteoporotic (SUM < 6mm, AVG < 5mm, CBI < 0.25). Statistical analyses were performed to examine each cortical parameter's accuracy in predicting metaphyseal BMD and in classifying tibial metaphyseal bone as Normal (t > 185 mg/cm^3), Osteopenic (185 > t > 115 mg/cm^3) or Osteoporotic (t < 115 mg/cm^3).

RESULTS: The most accurate estimate of metaphyseal BMD was provided by the AVG with an adjusted correlation coefficient of 0.534 and a predictive accuracy of 73% for discrimination between normal, osteopenic and osteoporotic bone (Figure 2). Lower values were provided by the CBI with a correlation coefficient of 0.217 and a predictive accuracy of 40%, and the SUM with a correlation coefficient of 0.475 and a predictive accuracy of 35%.

CONCLUSIONS: Our results indicate that simple indices from plain radiographs can offer insight into tibial metaphyseal bone quality. The most accurate predictions are provided by the AVG. With further refinement, this parameter could offer a simpler and cheaper solution for estimating the BMD of the proximal tibia. Ideally, this parameter would be measured as an indicator for preoperative planning for TKR, especially in revision cases.

Figures

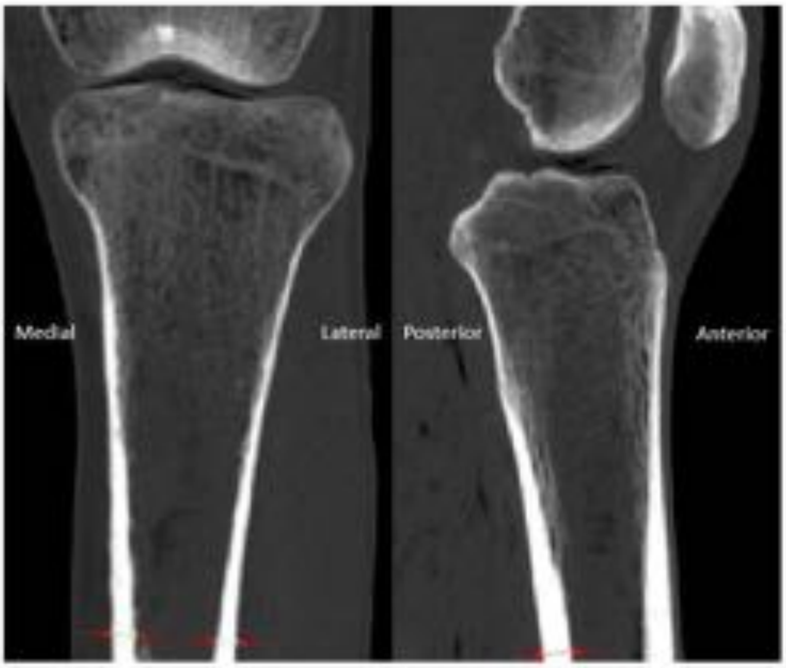

Figure 1. Anteroposterior and lateral views of a left knee specimen showing the three measured cortices.

Figure 1

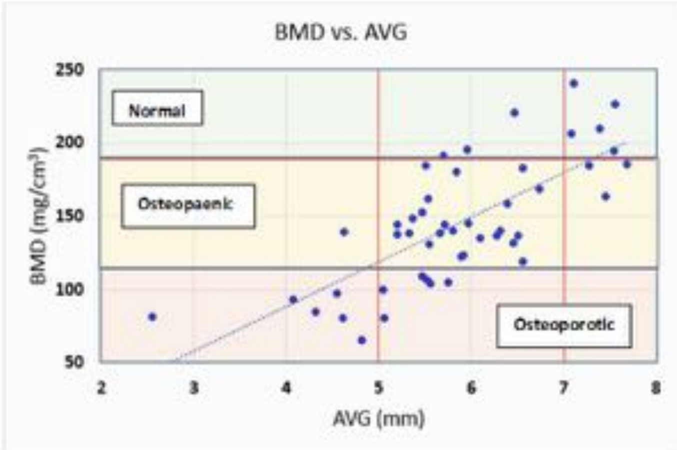

Figure 2. The average width of the medial, lateral, and posterior tibial cortices, 130mm distal to the joint line vs. the bone mineral density of a metaphyseal cross-section (thickness: 3.5mm), 10mm distal to the tibial medial plateau.

Figure 2

#5864

Relationship Between Coronal and Rotational Alignments of the Lower Extremity in Patients With Valgus Osteoarthritic Knees

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Background: Authors sought to determine the degree of lateral condylar hypoplasia of distal femur was related to degree of valgus malalignment of lower extremity in patients who underwent TKA. Authors also examined the relationships between degree of valgus malalignment and degree of femoral anteversion or tibial torsion.

Methods: This retrospective study included 211 patients (422 lower extremities). Alignment of lower extremity was determined using mechanical tibiofemoral angle (mTFA) measured from standing full-limb AP radiography. mTFA was described positive value when it was valgus. Patients were divided into three groups by mTFA; more than 3 degrees of valgus (valgus group, n = 31), between 3 degrees of valgus to 3 degrees of varus (neutral group, n = 78), and more than 3 degrees of varus (varus group, n = 313).Condylar twisting angle (CTA) was used to measure degree of the lateral femoral condylar hypoplasia. CTA was defined as the angle between clinical transepicondylar axis (TEA) and posterior condylar axis (PCA). Femoral anteversion was measured by two methods. One was the angle formed between the line intersecting femoral neck and the PCA (pFeAV). The other was the angle formed between the line intersecting femoral neck and clinical TEA (tFeAV). Tibial torsion was defined as a degree of torsion of distal tibia relative to proximal tibia. It was determined by the angle formed between the line connecting posterior cortices of proximal tibial condyles and the line connecting the most prominent points of lateral and medial malleolus. Positive values represented relative external rotation. Negative values represented relative internal rotation.

Results: Greater lateral femoral condylar hypoplasia was related to increased valgus alignment of lower extremity. Correlation coefficient between mTFA and CTA was 0.253 ($p < 0.001$). Valgus group showed increased CTA, which was 10.2° ± 1.9°. CTA was 7.4° ± 2.5° in neutral group and 6.6° ± 4.8° in varus group. There was significant positive correlation between the degree of valgus alignment and the degree of femoral anteversion ($r = 0.145$, $p = 0.003$). pFeAV was 16.7° ± 5.8° in valgus group, 12.1° ± 6.0° in neutral group and 10.9° ± 7.0° in varus group. There was no correlation between degree of valgus alignment and degree of femoral anteversion ($r = 0.060$, $p = 0.218$). In terms of tibial torsion, increased valgus malalignment was associated with increased tibial torsion ($r = 0.374$, $p < 0.001$). Valgus group showed increased tibial torsion than other groups. Tibial torsion was 32.6° ± 6.2° in valgus group, 26.3° ± 6.9° in neutral group and 22.6° ± 7.2° in varus group.

Conclusions: Increased valgus alignment of lower extremity was related to greater lateral femoral condylar hypoplasia. However, increased valgus alignment was not related to degree of femoral anteversion whereas it was related to increased external tibial torsion. Our findings should be considered when determining proper rotational alignment in TKA.

#5860

Understanding the Pathological Changes of Varus Knee on MRI Can Lead to a Better Algorithm to Balance the Knee

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Introduction:

Most of the algorithm available today to balance varus knee is based on a surgeon's hands-on experience without full understanding of pathological anatomy of varus knee. The high-resolution MRI allows us to recognize the anatomical details of the posteromedial corner and the changes of the soft tissue associated with the osteoarthritis and varus deformity.

We have in this study, reviewed 60 cases of severe varus knee scheduled for TKR and compared it to normal MRI and those MRI were evaluated and read by a musculoskeletal radiologist. We have documented clearly the changes that happens in soft tissue, leading to tight medial compartment. We will also show multiple short intra-operative video confirming that MRI findings.

Material & method:

We have retrospectively reviewed the MRI on 60 patients with advanced osteoarthritis varus knee. We also reviewed 20 MRI for a normal knee matched for age.

We evaluated the posteromedial complex and MCL in sagittal PD-weighted VISTA to check the alignment of the MCL and posteromedial complex and the associate MCL bowing and deformity that could happen in osteoarthritis knee. We have measured the thickness of the posteromedial complex and the posterior medial bowing of the superficial MCL and the involvement of the posterior oblique ligament in those patients.

To measure the posterior bowing of the MCL, a line was drawn through the posterior aspect of both menisci and we measured the distance between the posterior edge of MCL to that line in actual image. To measure the thickness of the posteromedial complex, we measured it at two areas in the posterior medial corner posteriorly at the level of the medial meniscus.

Measuring the medial bowing of the MCL was done by a line drawn through the medial edge of the femoral condyle and the tibial condyle at the level of the medial meniscus to the inner aspect of the MCL. The normal distance between the posterior aspects of the MCL to the posterior meniscus line was approximately measured 2 cm. in average.

Results:

We were able to recognize and measure the medial deviation of MCL in all arthritic knees due to the deformity and the effect of the medial margin osteophyte and medial extrusion of the meniscus. Thickening of posteromedial complex was recognized in the majority of the cases with prominent thickening seen in 50/60 knees with average thickness measuring approximately 1.2 cm due to the synovial thickening, adhesions, granulation tissue, degenerated medial meniscus, and involvement of the posterior oblique ligament and the capsular branch of the semimembranosus tendon, as well as the oblique popliteal ligament.

The involvement of posterior oblique ligament were seen in majority of the cases. In 55 cases we have showed a heterogeneous appearance of the ligament and loss of normal signal within the postero medial complex and we have documented that the oblique ligament will cause the posterior bowing of the MCL. The medial bowing of the MCL is also correlated to the severity of the varus deformity with an average distance to the normal medial line of the medial meniscus measuring approximately 1.1 cm

Discussion:

Our study shows that the changes affecting the superficial MCL is likely to be secondary to the obvious changes involving the posteromedial complex and to the marginal osteophyte as well as the extrusion of the medial meniscus. Also, we have confirmed that there are deforming structures such as the oblique ligament with adhesion and thickening with all the posterior medial complex. Those changes clearly caused the posterior bowing to the superficial MCL without an actual shortening of the ligament. The scarring tissue in the posteromedial corner and the adhesion is acting as a soft phyte tensioning and deforming the ligament and the posterior capsule. The oblique ligament act as a deforming forces forcing the superficial MCL to bow posteriorly. The lengths of the superficial MCL stayed the same.

Conclusion:

The conventional wisdom of releasing the distal attachment of the superficial medial MCL to balance knee has to be a challenge based on our MRI finding. Releasing the superficial MCL can sometimes lead to a major instability of the knee requiring a more constrained implant. Our MRI assessment clearly showed that the Superficial MCL is deformed because of posterior bowing and medial bowing and considerable thickening of the posteromedial corner, as well as the accompanying osteophyte. We believe that clearing the superficial MCL and excising those thickened scar tissue in the posterior medial corner will enable us to balance the knee without creating instability

#5634

A Robotic Based Analysis of Human Cadaveric Knees to Determine Influences of Soft Tissues on Joint Laxity

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Introduction:

ACL rupture is a common sports injury at the knee. Traditionally, this indication is treated by an isolated reconstruction of the ACL [1]. Various publications report an improved outcome by using a combined ACL and ALL reconstruction technique [2 – 4]. Therefore, an objective evaluation of the influence of these ligaments on joint laxity is helpful in determination of adequate surgical approaches.

In this study, a robotic test procedure of human knee joint laxity is presented to systematically asset the isolated influence of the important ligaments.

Methods:

Laxity data of five anonymized fresh-frozen human cadaveric left knee specimens were acquired.

Specimens were prepared by dissecting unneeded tissue and properly exposing ALL, ACL, PCL, MCL and LCL. The distal end of the femur and the proximal end of the tibia were cut and secured in aluminum cylinders using polymethyl methacrylate (PMMA).

Experimental testing was performed using a six degree-of-freedom industrial robot. A six degree-of-freedom force-torque sensor was attached to the robots end-effector. Steel alloy clamps were used to connect the tibia to the robot manipulator and the femur to the base, respectively (Figure 1). Joint coordinate systems were defined following the convention of Grood et al. [5].

A passive path was recorded by increasing the flexion angle incrementally from 0° to 90° in steps of 1°.

Figure 2 shows the experimental testing protocol consisting of a series of applied forces and torques to the knee joint in varying flexion angles in the three physiological directions: anterior-posterior translation, varus-valgus angulation and internal-external rotation.

Tests were performed sequentially after stepwise dissection of the ALL, ACL, and PCL to determine the influence of these ligaments on knee laxity and to detect alterations of relative movements between femur and tibia.

Loads were applied in the tibial coordinate system while recording the relative motion between the joint coordinate systems. To assure contact between the articulating partners, a compressive load of 10N was used. For the control loop, tolerances of +/- 5N and +/- 10Nm have been used respectively.

Results:

Figure 3 shows the influence of the ALL, ACL and PCL on knee joint laxity of the specimens for (1) anterior translation and (2) internal rotation. Due to collision problematics in high flexion, the number of specimens varies between 2 and 5.

The ALL is primarily stabilizing internal rotation indicated by an increased internal rotation comparing ALL and ALL & ACL deficient specimens.

The ACL is primarily stabilizing anterior translation and internal rotation. From 0° to 30° knee flexion, an increase of anterior laxity is observed, followed by a decrease to a minimum at a flexion angle of 90°.

The PCL did not show any significant change of joint laxity on anterior translation or internal rotation, respectively.

Conclusion:

The described experimental test method allows for a reproducible measurement of knee joint laxity for precisely defined conditions. The acquired datasets showed consistent trends over all specimens and correspond well with other studies [6, 7]. For more significant results an increased number of specimens is needed.

Figures

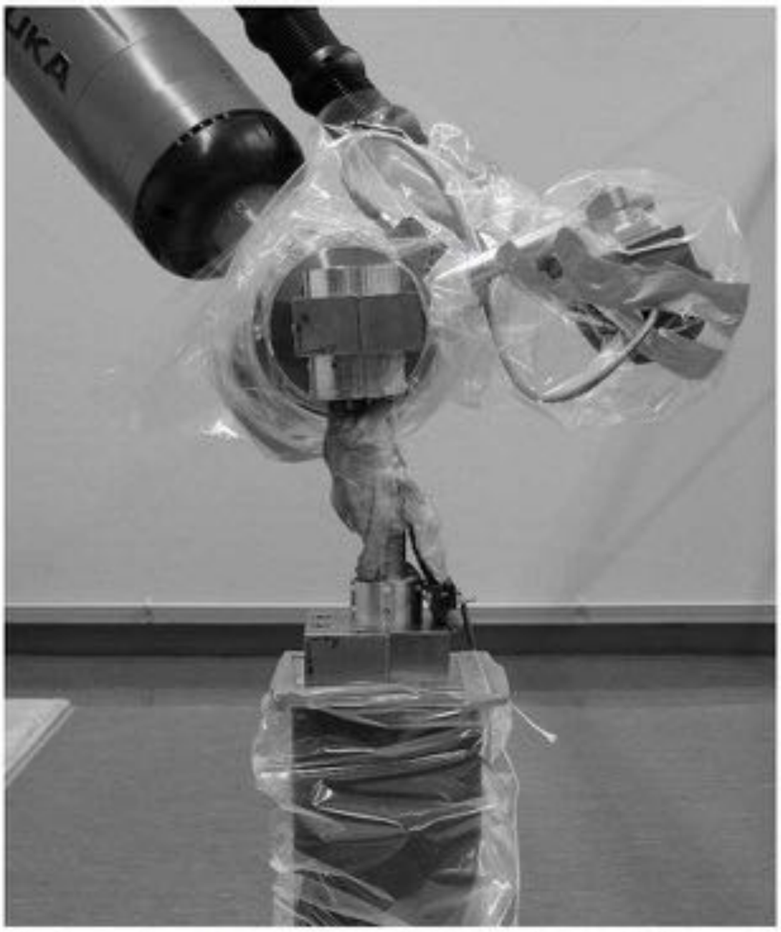


Figure 1: Experimental test setup with the tibia attached to the robot manipulator and the femur fixed to the base

Figure 1

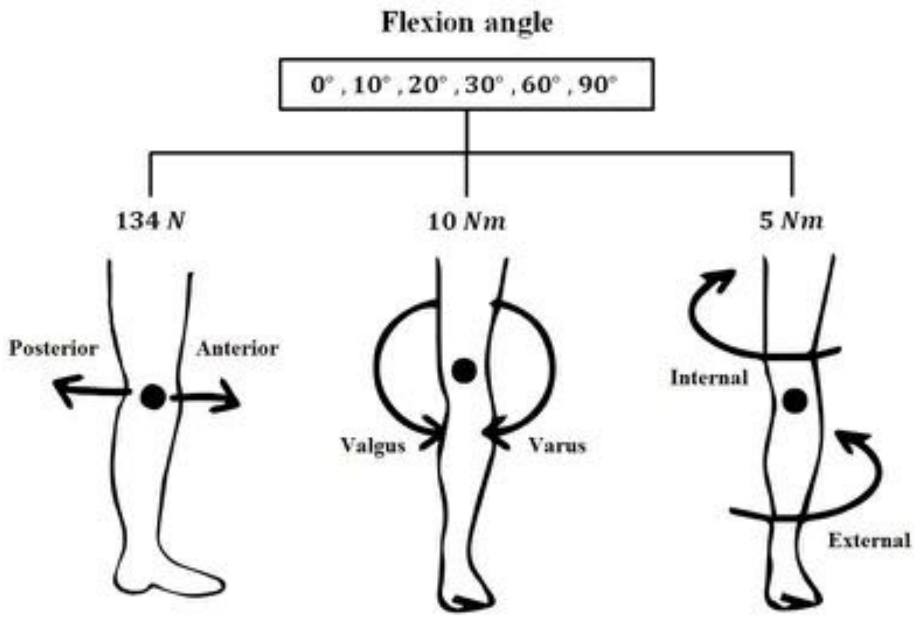
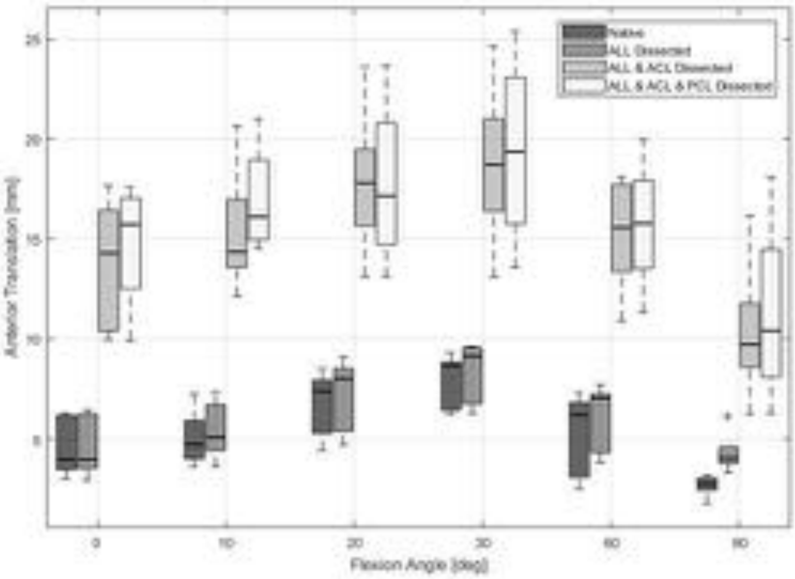
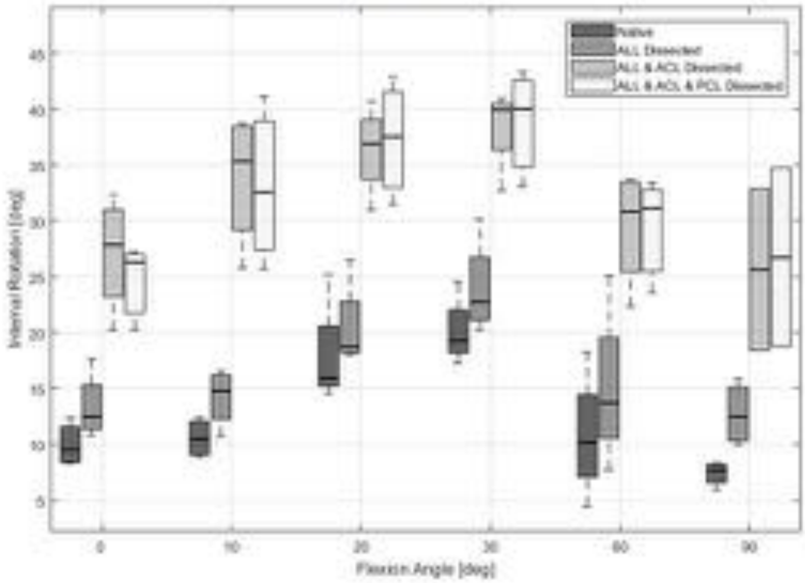


Figure 2: Test protocol of the laxity tests

Figure 2



(1)



(2)

Figure 3: Boxplots of knee joint laxity of specimens showing median (central mark), 25th and 75th percentiles (box), extrema (whiskers) and outliers (+)

Figure 3

References

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Figure 4

the Morphological Appearance of the Posterior Cruciate Ligament After Cruciate Retaining Total Knee Arthroplasty

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Background:

In Total Knee Arthroplasty (TKA), although no conclusion has been drawn regarding the merits of Cruciate Retaining (CR) TKA and Posterior Stabilizing (PS)TKA, it is necessary for CR-TKA to maintain the function of posterior cruciate ligament (PCL) postoperatively.

The PCL plays an important role in femoral rollback and maintaining axial stability in a normal knee. However, it remains uncertain as to whether the PCL keeps its form and function after CR-TKA.

Objectives:

To observe the morphological change of the PCL according to the flexion angle of the knee among the cases with CR-TKA.

Study Design & Methods:

We examined 134 knees(male: 5knees, female : 129knees) that underwent primary TKA because of osteoarthritis or rheumatoid arthritis of the knee between January 2014 andã€€October 2016.

For these patients, we used cruciate retaining FINE KNEE (TEIJIN NAKASHIMA MEDICAL CO., LTD Japan) made of titanium. MRI(HITACHI AIRISâ…¡confort 0.3T) T2 weighted sagittal image was taken between 6 to 12 months after surgery.

We performed MRI imaging in four positions at 30 °, 60 °, 90 ° knee flexion angle, and at maximum flexion of the knee. We defined the four groups of the PCL taken at 30, 60, 90 degrees flexion and maximum flexion as the F30, F60, F90, and the FM respectively.

Then we evaluated the morphology of the PCL in CR-TKA.The form of the PCL was classified into three types based on the model Nakagawa et al reported in normal knees. They were forward convex, straight and posterior convex.

We observed how the PCL changes its morphology depending on the flexion angle after CR-TKA operation.We excluded cases where the shape of the PCL was unclear in any of the four positions.

Results:

The morphology of the PCL were as follows; in the F30*(*front convex :0 knees, straight : 2 knees, posterior convex : 132knees), F 60 (front convex : 0 knees, straight : 38 knees, posterior convex : 96 *knees)*, F 90 *(*front convex : 11knees, straight 112 knees, posterior convex : 11 knees), FM (front convex : 93 knees, straight : 41 knees, posterior convex : 0 knees).

Thus in 98% cases of the F30 and 72% of the F60, the PCL showed posterior convexity with no front convexity cases in both groups.

On the other hand, in 84% of the cases in the F90 the PCL exhibited straight configuration.In the FM, 69% of the patients demonstrated front convexity in their PCL and 31% of the cases showed straight shape and there were no examples of posterior convex in the FM.

Conclusions:

Based on the findings of this study, it is inferred that the shape of the PCL after CR-TKA changes from a posterior convex to a straight forward with a forward convex as the knee flexion angle increases.

It was shown that the change of the PCL morphology accompanying the knee flexion after CR-TKA is quite similar to that of a normal knee as reported by Nakagawa et al.

A Robot Study on Mobile Bearing TKA Laxities and Kinematics*

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Introduction: Total-knee-arthroplasty (TKA) is used to restore knee function and is a well-established treatment of osteoarthritis. Along with the widely used fixed bearing TKA design, some surgeons opt to use mobile bearing designs. The mobile-bearing TKA is believed to allow for more freedom in placement of the tibial plate, greater range of motion in internal-external (IE) rotation and greater constraint through the articular surface. This current study evaluates 1) the kinematics of a high constraint three condyle mobile bearing TKA, 2) the insert rotation relative to the tibia, and 3) compares them with the intact knee joint kinematics during laxity tests and activities-of-daily-living (lunge, level walking, stairs down). We hypothesize that 1) in contrast to the intact state the anterior-posterior (AP) stability of the implanted joint increases when increasing compression level while 2) maintaining the IE mobility, and that 3) the high constraint does not prevent differential femorotibial rollback during lunge.

Methods: Six fresh-frozen human cadaveric knee joints with a mean donor age of 64.5 (±2.4) years and BMI of 23.3 (±7.3) were tested on a robot (KR140, KUKA) in two different states: 1) intact, 2) after implantation of a three condyle mobile bearing TKA. The tibia plateau and the insert of each tested specimen were equipped with a sensor to measure the insert rotation during testing. Laxity tests were done at extension and under flexion (15°, 30°, 45°, 60° 90°, 120°) by applying subsequent forces in AP and medial-lateral (ML) of ±100N and moments in IE and varus-valgus (VV) rotation (6Nm/4Nm, 12 Nm/-). Testing was performed under low (44N) and weight bearing compression (500N). Loading during the lunge, level walking and stairs descent activity was based on in-vivo data. Resulting data was averaged and compared with the kinematics of the intact knee.

Results: Increasing the joint compression resulted in a 90% reduced AP laxity (increased stability) (Figure 1, 2) for the implanted case while the intact knee laxity stayed similar. In high compression the implanted IE mobility was reduced by 45% for low and mid flexion angles and by 20% for high flexion angles, while the intact knee IE mobility was reduced by 30% at low and mid flexion and 20% at high flexion (Figure 2). The trend of the rollback behaviour was similar for the implanted and intact joints and showed higher lateral than medial rollback (Figure 3 A). The average insert rotation (Figure 3 B) was highest during level walking (+ 5° to -2.5°) and lowest during lunge (-3.5° to 2.5° over flexion).

Conclusion: The established hypotheses were supported by the results. Increasing the joint compression in the mobile bearing design stabilized the knee in the AP direction and maintained the IE mobility similar to the intact knee. This can be directly related to the design of the TKA articular surface, which has a high impact on constraint as soon as the joint is loaded. However, the high constraint of the TKA did not prevent differential rollback.

*Cadaveric studies are not necessarily indicative of clinical results.

Figures

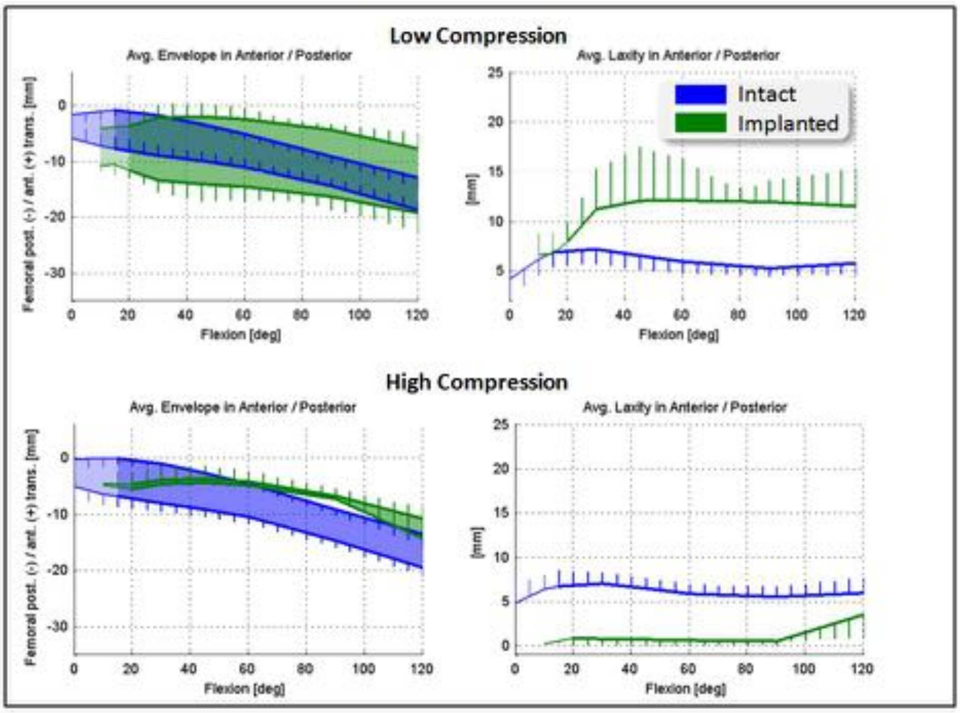

Figure 1: Averaged low and high compression femorotibial envelope and laxity in AP (midpoint between flexion facet centers (FFC))

Figure 1

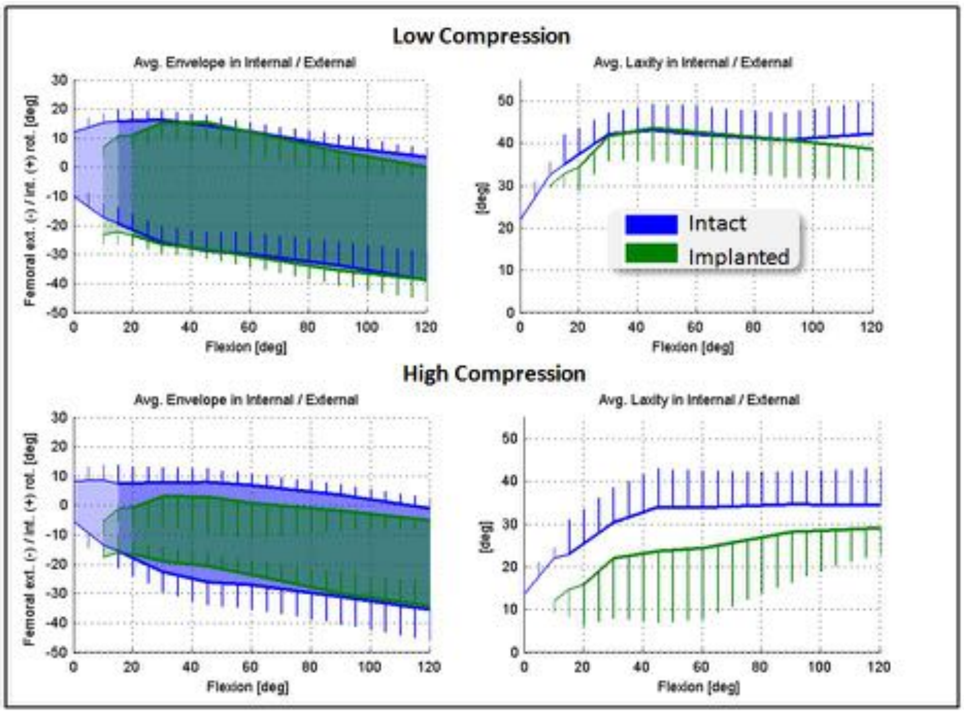

Figure 2: Averaged low and high compression femorotibial envelope and laxity in IE (midpoint between FFCs)

Figure 2

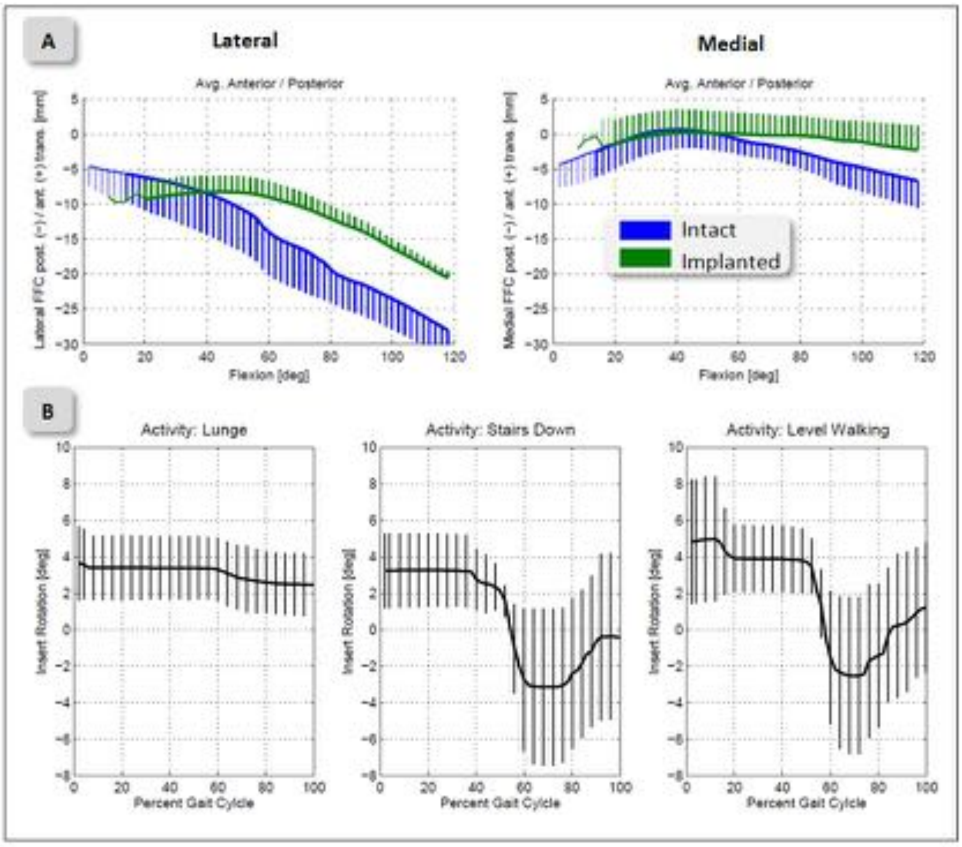

Figure 3: A) Average femorotibial relative position in AP of the medial and lateral condyle (FFCs) during lunge activity, B) insert rotation during activities per specimen (center axis of poly pin)

Figure 3

#5744

The Effect of Posterior Condyle Sizing on Extension in Total Knee Arthroplasty

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Introduction & aims:

Optimizing the flexion and extension gaps in TKA is important in attaining good range of motion and joint stability. Traditional teaching dictates that the extension gap, and therefore ability to achieve full extension, is affected by the distal femur resection and tibial resection. However, existing evidence has demonstrated that extension gap also improves with a smaller posterior femoral condyle. To date, validation with actual range of motion has not been performed.

Method

Seventeen patients underwent TKA (Zimmer Nexgen) in this prospective, single surgeon,single center study. Computer navigation (Orthosoft) was utilized to measure the intra-operative range of motion and coronal alignment. In each patient, after the appropriately sized femoral and tibial cuts were made, the “standard” and “minus” posterior femoral condyle trial prostheses were compared and coronal and sagittal range of motion were recorded. Statistics were performed using a two-tailed paired t-test.

Results

There was a mean improvement of 4.5 degrees of extension in patients fitted to a minus trial compared to the standard trial ($p < 0.01$). Coronal balance in extension also showed an improvement towards anatomical alignment of 0.3 degrees with the minus trial, however this was not statistically significant ($p = 0.23$). There was no evidence of coronal mid-flexion instability as a consequence of minus sizing with a mean difference of 0.6 degrees towards anatomic with the knee at 30 degrees ($p = 0.19$), 60 degrees ($p = 0.47$) and 90 degrees ($p = 0.52$).

Conclusions

The minus sized posterior condyle prosthesis resulted in improved knee extension and is a useful adjuvant in optimizing TKA sagittal balance.

Accuracy of Density-Modulus Relationships Used in Finite Element Modeling of the Shoulder

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INTRODUCTION: Density-modulus relationships are often used to map the mechanical properties of bone based on CT-intensity in finite element models (FEMs). Although these relationships are thought to be site-specific, relationships developed for alternative anatomical locations are often used regardless of bone being modeled. Six relationships are commonly used in finite element studies of the shoulder; however, the accuracy of these relationships have yet to be compared. This study compares the accuracy of each of these six relationships ability to predict apparent strain energy density (SED_{app}) in trabecular bone cores from the glenoid.

METHODS: Quantitative-CT (QCT) (0.625 mm isotropic voxels), and µ-CT scans (0.032 mm isotropic voxels) were obtained for fourteen cadaveric scapulae (7 male, 7 female). Micro finite element models (µ-FEMs) were created from 98 virtual ‘cores’ using direct conversion to hexahedral elements. Two µ-FEM cases were considered: homogeneous tissue modulus of 20 GPa, and heterogeneous tissue modulus scaled by CT intensity of the µ-CT images (196 models). Each µ-FEM model was compressively loaded to 0.5% apparent strain and apparent strain energy density (SED_{app}) was calculated. Additionally, each of the six density-modulus relationships were used to map heterogeneous material properties to co-registered QCT-derived models (588 models in total) (Figure 1). The loading and boundary conditions were replicated in the QCT-FEMs and the SED_{app} was calculated and compared to the µ-FEM SED_{app}. To account for more samples than donors, restricted maximum likelihood estimation (REML) linear regression compared µ-FEM SED_{app} and QCT-FEM SED_{app} for each relationship.

RESULTS: When considering comparisons between QCT-FEMs and µ-FEMs with a homogeneous tissue modulus, near absolute statistical agreement (Y=X) was observed between the µ-FEMs and the QCT-FEMs using the Morgan et al. (2003) pooled relationship (Figure 2-Table 1). Not surprisingly, due to the similarity between the two relationships, the Gupta & Dan (2004) and Carter and Hayes (1977) models showed near identical REML linear regression fit parameters. All relationships other than the Morgan et al. (2003) pooled relationship, greatly underestimated the µ-FEM apparent strain energy density (SED_{app}) when considering a homogeneous tissue modulus in the µ-FEMs. The same result with the pooled relationship did not hold true when heterogeneous tissue modulus was considered in the µ-FEMs. The Büchler et al., (2002) relationship most accurately predicted the SED_{app} for this comparison (Figure 3-Table 2). Interestingly, the Gupta & Dan (2004) and Carter and Hayes (1977) relationships again showed near identical REML linear regression fit parameters.

DISCUSSION: This study compared the six most common density-modulus relationships used to map mechanical properties of bone in shoulder FE studies. It was found that when considering a homogeneous tissue modulus for µ-FEMs, relationships pooled from alternative anatomical locations may accurately predict the mechanical properties of glenoid trabecular bone. However, when considering a heterogeneous tissue modulus, this did not hold true. Further studies to determine if these relationships can be translated to whole bones may provide insight into the predictive capabilities of using pooled density-modulus equations in the mapping of mechanical properties in future FEMs of the shoulder.

Figures

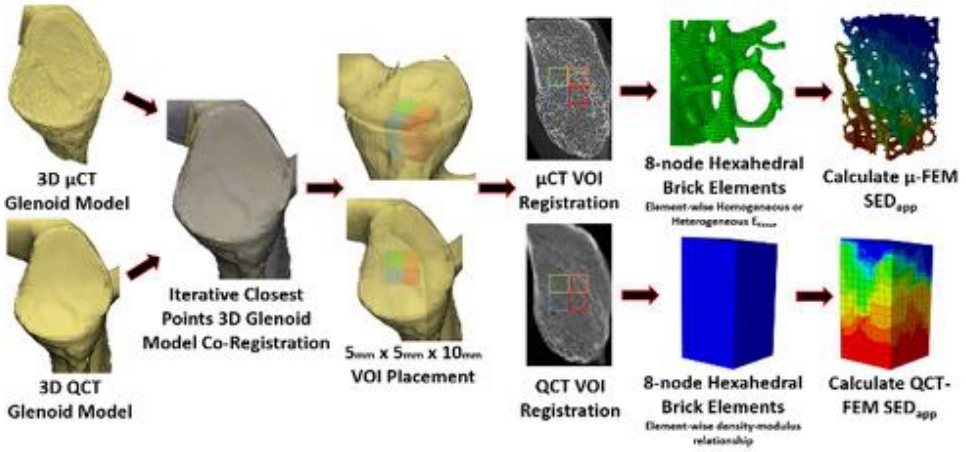

Figure 1: The workflow used to create QCT-FEMs and µ-FEMs. Three-dimensional models of the µ-CT glenoid and QCT-glenoid (gray) were co-registered. Rectangular volumes of interest (VOIs) were placed and co-registered with the µ-CT and QCT images. Hexahedral brick elements were created for each of the µ-FEMs and QCT-FEMs using custom code, and boundary conditions replicated between the µ-FEMs and QCT-FEMs.

Figure 1

Table 1: Results from restricted maximum likelihood estimation linear regression fits of apparent strain energy (SED_{app}) predictions between QCT-FEMs and homogeneous tissue modulus µ-FEMs (20 GPa)

QCT-FEM SED_{app} = m µ-FEM SED_{app} + b	r^2	m	b	SE	SE/mean
(Morgan et al., 2003) Pooled	0.933	0.979	0.0066	0.0049	17.5%
(Morgan et al., 2003) Femur	0.937	0.739	0.0098	0.0037	14.4%
(Gupta and Dan, 2004)	0.891	0.326	-0.0013	0.0019	32.2%
(Büchler et al., 2002)	0.919	0.476	0.0026	0.0028	21.6%
(Carter and Hayes, 1977)	0.903	0.320	-0.0024	0.0018	31.4%
(Schaffler & Burr, 1988) (Rice et al., 1988)	0.940	0.105	0.0013	0.0005	13.7%

Figure 2

Table 2: Results from restricted maximum likelihood estimation linear regression fits of apparent strain energy (SED_{app}) predictions between QCT-FEMs and heterogeneous tissue modulus µ-FEMs

QCT-FEM SED_{app} = m µ-FEM SED_{app} + b	r^2	m	b	SE	SE/mean
(Morgan et al., 2003) Pooled	0.926	1.914	0.0091	0.0052	18.5%
(Morgan et al., 2003) Femur	0.928	1.431	0.0119	0.0040	15.4%
(Gupta and Dan, 2004)	0.892	0.638	-0.0010	0.0019	32.2%
(Büchler et al., 2002)	0.911	0.945	0.0013	0.0030	22.7%
(Carter and Hayes, 1977)	0.902	0.623	-0.0007	0.0018	31.9%
(Schaffler & Burr, 1988) (Rice et al., 1988)	0.948	0.211	0.0015	0.0005	12.9%

Figure 3

#5771

Generation of Anatomic Shapes With Prescribed Features From Statistical Shape Models Using Machine Learning

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The use of shape models to represent the complex geometry of bone is a convenient and powerful tool for capturing anatomical variation and assisting with matching implant geometry to anatomic geometry. Unfortunately, shape model modes as determined with principal component analysis often do not correspond to anatomic features or the anatomic references that have been traditionally used as part of anatomic and joint implant research. While shape modes and anatomic features can be correlated, the relationships between shape modes and anatomic features may be complex and multi-variate.

Machine learning technologies have been rapidly developing and the availability of standardized libraries such as scikit-learn are increasing the applications of machine learning. We hypothesized that a machine learning model would be able to describe the relationships between anatomic feature geometry and shape model modes and combine the relationship into a 'virtual' mode. The use of a virtual mode would allow the production of bone shapes that have specific anatomic features of interest to the end user. A potential application of the virtual mode would be to produce humeri that have specified head radius.

To evaluate this concept, an existing library of cadaveric humeri were utilized to create a virtual mode describing head radius and articular surface inclination. Forty-three human humeri were CT scanned, segmented, and labeled with correspondence points in the ShapeWorks platform (Scientific Computing Institute, University of Utah). Correspondence points on the articular surface were identified and used to calculate head radius and inclination (the 'Anatomic Features'). Principal component analysis was conducted on all specimen correspondence points to create a shape model. Parallel analysis of the PCA loading values identified 5 modes of significant variation which included 88.4% of the total variation within the population. The RandomForestRegressor function in scikit-learn was then used to model the relationship between PCA loadings and the Anatomic Features as a virtual mode. Finally, using the virtual mode with target values for the anatomic features the corresponding point cloud of correspondence points was created (Figure 1).

Including more shape modes and more estimators produce better accuracy in reconstructing anatomic features (Table 1). The mean absolute error (MAE) obtained for head radius was 0.96 mm with n_estimators=n_modes=100. A larger, but still reasonable head radius MAE of 1.57 mm was achievable with n_estimators=n_modes=20. The virtual mode performed best when predicting in the mid range of the input features with increasing errors as the target value of the anatomic feature become more extreme (Figure 2). 'Over fitting' the data could be problematic if attempting to increase the accuracy of the when predicting extreme values of anatomic features. Initial results of this technique are promising and may allow generation of anatomic shapes that match traditional anthropometric measures.

Table 1. Mean absolute error of head radius from the shape model generated humeri.

Number of Shape Modes	Number estimators = 10	Number estimators = 100
10	3.92	3.73

10	3.92	3.73
100	1.00	0.96

Figures

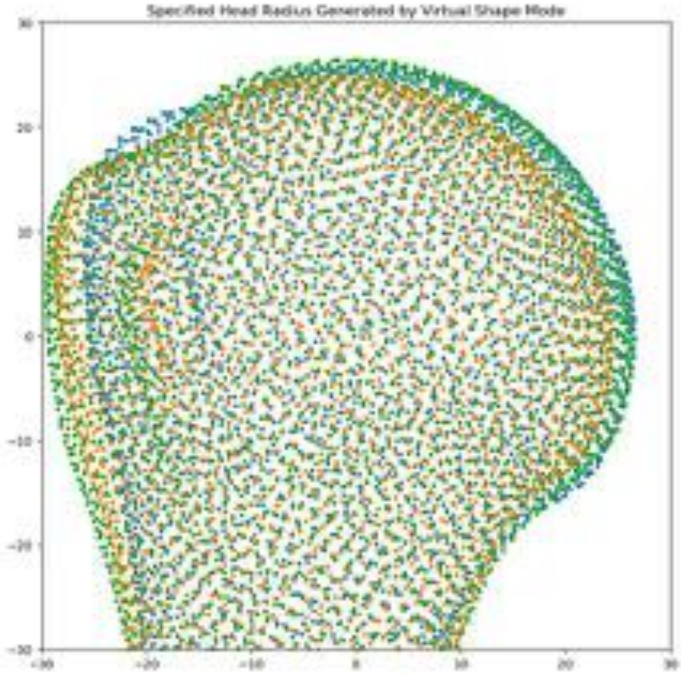

Figure 1

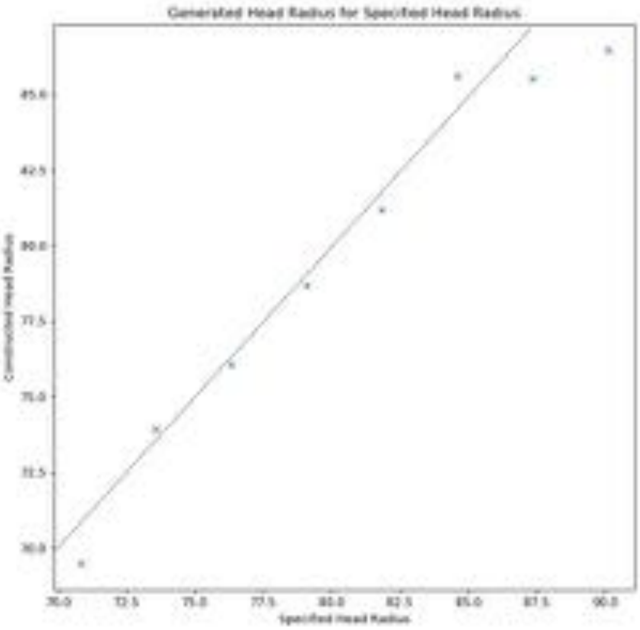

Figure 2

#5653

Validation of a Statistical Shape Model for Acetabular Bone Defect Analysis

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Introduction

Acetabular bone defects are still challenging to quantify. Numerous classification schemes have been proposed to categorize the diverse kinds of defects. However, these classification schemes are mainly descriptive and hence it remains difficult to apply them in pre-clinical testing, implant development and pre-operative planning. By reconstructing the native situation of a defect pelvis using a Statistical Shape Model (SSM), a more quantitative analysis of the bone defects could be performed. The aim of this study is to develop such a SSM and to validate its accuracy using relevant clinical scenarios and parameters.

Methods

An SSM was built on the basis of segmented 66 CT dataset of the pelvis showing no orthopedic pathology. By adjusting the SSM's so called modes of shape variation it is possible to synthetize new 3D pelvis shapes. By fitting the SSM to intact normal parts of an anatomical structure, missing or pathological regions can be extrapolated plausibly. The validity of the SSM was tested by a Leave-one-out study, whereby one pelvis at a time was removed from the 66 pelvises and was reconstructed using a SSM of the remaining 65 pelvises. The reconstruction accuracy was assessed by comparing each original pelvis with its reconstruction based on the root-mean-square (RMS) surface error and five clinical parameters (Figure 1 A). The influence of six different numbers of shape variation modes (reflecting the degrees of freedom of the SSM) and four different mask sizes (reflecting different clinical scenarios) was analyzed (Figure 1 B).

Results

The Leave-one-out study showed that the reconstruction errors decreased when the number of shape variation modes included in the SSM increased from 0 to 20, but remained almost constant for higher numbers of shape variation modes. For the SSM with 20 shape variation modes, the RMS of the reconstruction error increased with increasing mask size, whereas the other parameters only increased from Mask_0 to Mask_1, but remained almost constant for Mask_1, Mask_2 and Mask_3. Median reconstruction errors for Mask_1, Mask_2, and Mask_3 were approximately 3 mm in Center of Rotation (CoR) position, 2 mm in Diameter, 3° in inclination and anteversion, as well as 5 ml in volume.

Discussion

This is the first study analyzing and showing the feasibility of a quantitative analysis of acetabular bone defects using a SSM-based reconstruction method in the clinical scenario of a defect or implant in both acetabuli and incomplete CT-scans. Validation results showed acceptable reconstruction accuracy, also for clinical scenarios in which less healthy bone remains. Further studies could apply this method on a larger number of defect pelvises to obtain quantitative measures of acetabular bone defects.

Acknowledgements

The authors would like to thank the Charité Berlin for provision of CT-data sets.

Figures

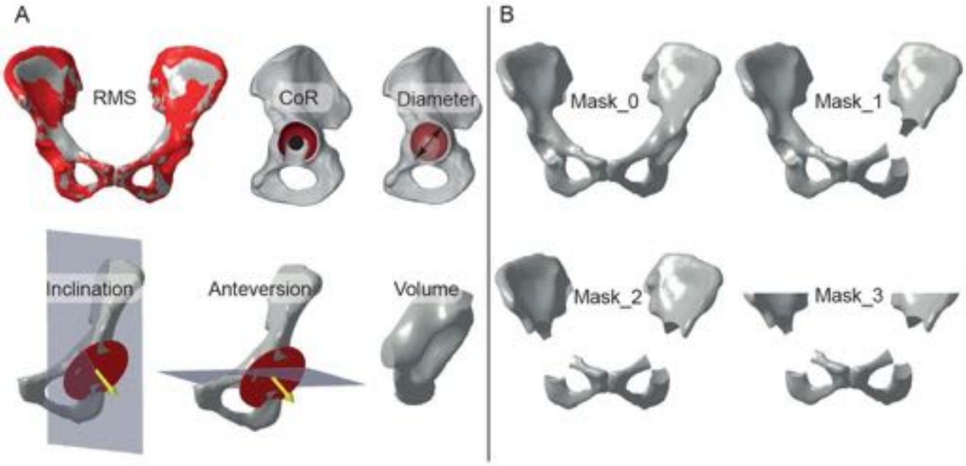

Figure 1: Validation parameters and clinical scenarios. (A) Parameters used to assess the validity of the reconstruction. (B) Ground truth of the reconstruction (Mask_0), scenario with one excluded acetabulum (Mask_1), scenario with both excluded acetabuli (Mask_2), and scenario with both acetabuli and the cranial areas of the os ilium excluded (Mask_3).

Figure 1

#5774

AI Generated 3D Point Cloud Representations of the Humerus

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Generative adversarial networks have been called “The hottest trend in AI” (Quartz 3/17/18). While public attention on AI is often focused on detremental consequences such as “Jordan Peele turns Obama into foul-mouthed fake-news PSA” (CNET 4/17/18) the applicatoin of AI techniques such as GANs can also be powerful tools towards improving medical science. For example, Insilico uses GAN technology to generate molecular structures with engineered properties (NVIDIA blog 2/8/17).

We hypothesized that a GAN would be ideal for simulating the the complex shape of human bone topolgy and that the resulting shapes would be suitable for use in digital modeling of new implant designs. An existing library of forty-three human humeri that were CT scanned, segmented, and labeled with correspondence points in the ShapeWorks platform (Scientific Computing Institute, University of Utah) were utilized. Principal component analysis was conducted (python / scikit-learn library) on the specimen correspondence points to create a shape model that represented the humeral geometry with a specified number of modes. As subset of these shape modes were then input into a GAN to serve as the initial training data. The GAN was formed with a generative neural network (scikit-learn MLPRegrssor) that output shape modes from random inputs and a discriminative neural network (scikit-learn MLPClassifier) that output the probability of an input shape mode as being real or generated. The discriminator’s probability was then fed back into the generator to retrain the generative model and produce new shape modes.

Subjectively, the GAN performed well (Figure 1) producing humeri shapes that were very good facsimiles of the input shapes. Because of the random inputs the GAN did sometimes produced odd shaped humeri (Figure 2). By machine learning standards, predicting only a few shape modes does not require intensive computing power or time and the network could quickly simulate, evaluate and train through thousands of shapes using a laptop computer. With appropriate inputs, GAN produced distributions of bony anatomy topologies could be useful for evaluating implant geometries.

Figures

Figure 1

Figure 2

#5760

Variations in the Mechanical Properties of Humeral Trabecular Bone: Towards Improving Computational Models of the Humerus

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INTRODUCTION: Mechanical property relationships used in the computational modeling of bones are most often derived using mechanical testing of normal cadaveric bone. However, a significant percentage of patients undergoing joint arthroplasties exhibit some form of pathologic bone disease, such as osteoarthritis. As such, the objective of this study was to compare the micro-architecture and apparent modulus (E_{app}) of humeral trabecular bone in normal cadaveric specimens and bone extracted from patients undergoing total shoulder arthroplasty.

METHODS: Micro-CT scans were acquired at 20 µm spatial resolution for humeral heads from non-pathologic cadavers (n=12) and patients undergoing total shoulder arthroplasty (n=10). Virtual cylindrical cores were extracted along the medial-lateral direction. Custom-code was used to generate micro finite element models (µFEMs) with hexahedral elements. Each µFEM was assigned either a homogeneous tissue modulus of 20 GPa or a heterogeneous tissue modulus scaled by CT-intensity. Simulated compression to 0.5% apparent strain was performed in the medial-lateral direction. Morphometric parameters and apparent modulus-volume fraction relationships were compared between groups.

RESULTS: Comparing morphometric parameters (Figure 2-Table 1), arthroplasty patients had significantly larger bone volume fractions ($p = .023$) and mean trabecular separation ($p = .031$), but no significant differences in mean trabecular thickness ($p = .060$) or trabecular number ($p = .178$). Variations were observed in the fit curves between normal and arthroplasty cases, with normal bone being best fit by power relationships, and arthroplasty bone exhibiting a more linear relationship (Figure 3-Table 2). There was no significant difference in mean apparent modulus for homogeneous tissue moduli ($p = .060$) but was a significant difference for heterogeneous tissue moduli ($p = .038$) (Figure 1).

DISCUSSION: Consistent with previously developed relationships that map apparent mechanical properties, normal cadaveric bone was best fit by a power relationship with an exponential coefficient over 2. However, the apparent modulus-volume fraction relationship in the arthroplasty patient bone exhibited a more linear relationship. These results suggest that the architectural and mechanical properties of normal cadaveric and arthroplasty patient trabecular bone are not equal. Since these relationships are used to map apparent mechanical properties to computational models, these preliminary results suggest that relationships derived from cadaveric normal bone may map the apparent mechanical properties differently than patients who undergo arthroplasty. Additional samples added to this dataset will allow for mechanical property relationships to be developed that account for these bone mechanical property variations. This has the potential to greatly improve the computational modeling of patients undergoing arthroplasty procedures and computational models that are used to design and improve shoulder arthroplasty components.

Figures

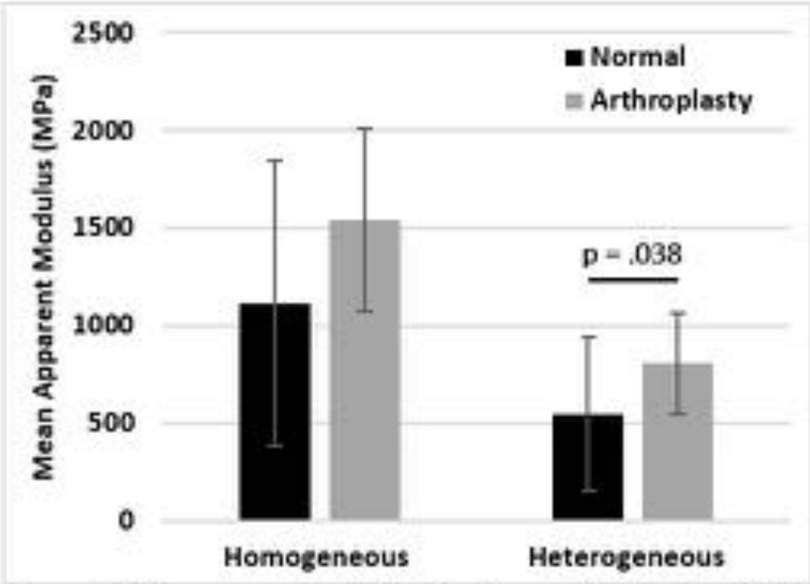

Figure 1: Mean apparent modulus for the normal and arthroplasty groups with homogeneous or heterogeneous tissue moduli. Mann-Whitney Rank Sum Test.

Figure 1

Table 1: Three-dimensional morphometric parameters of trabecular cores from the normal and arthroplasty groups.

Parameter	Group		p-value
	Normal (n=12)	Arthroplasty (n=10)	
BV/TV	0.20 ± 0.02 (0.14 – 0.31)	0.26 ± 0.07 (0.19 – 0.39)	**.023[a]**
Tb.Th* (mm)	0.198 ± 0.020 (0.151 – 0.225)	0.237 ± 0.047 (0.174 – 0.316)	.060[b]
Tb.Sp* (mm)	0.808 ± 0.097 (0.688 – 0.979)	0.709 ± 0.102 (0.587 – 0.947)	**.031[a]**
Tb.N* (1/mm)	0.998 ± 0.201 (0.741 – 1.432)	1.099 ± 0.116 (0.935 – 1.259)	.178[a]

Values are mean ± SD (range). All values were calculated using SkyScan CTAn (Bruker micro-CT, Kontich, BE) based on 3D morphometric calculations. BV/TV – Bone Volume/Total Volume; Tb.Th* – Mean Trabecular Thickness; Tb.Sp* – Mean Trabecular Separation; Tb.N* – Trabecular Number. Significant values ($p < .05$) are bolded. [a]Unpaired t-tests. [b]Mann-Whitney Rank Sum Test

Figure 2

Table 2: Apparent modulus-bone volume fraction power fit regression for the normal and arthroplasty trabecular bone cores with homogenous or heterogeneous tissue moduli.

$E_{app} = a\left(\frac{BV}{TV}\right)^b$	a	b	r^2	SSE (MPa)	SSE/Mean (%)
Normal Group Homogeneous E_{tissue}	**39900**	**2.269**	**0.914**	**224**	**20.0**
Normal Group Heterogeneous E_{tissue}	**31350**	**2.589**	**0.967**	**74**	**13.5**
Arthroplasty Group Homogeneous E_{tissue}	**4608**	**0.812**	**0.503**	**349**	**22.6**
Arthroplasty Group Heterogeneous E_{tissue}	**2983**	**0.971**	**0.634**	**167**	**20.6**

SSE – Standard error of the estimate

Figure 3

#5783

Assessing Hip Separation and Instability Using a Validated Forward Solution Model

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During the preoperative examination, surgeons determine whether a patient, with a degenerative hip, is a candidate for total hip arthroplasty (THA). Although research studies have been conducted to investigate in vivo kinematics of degenerative hips using fluoroscopy, surgeons do not have assessment tools they can use in their practice to further understand patient assessment. Ideally, if a surgeon could have a theoretical tool that efficiently allows for predictive post-operative assessment after virtual surgery and implantation, they would have a better understanding of joint conditions before surgery.

The objectives of this study were (1) to use a validated forward solution hip model to theoretically predict the in vivo kinematics of degenerative hip joints, gaining a better understanding joint conditions leading to THA and (2) compare the predicted kinematic patterns with those derived using fluoroscopy for each subject.

A theoretical model, previously evaluated using THA kinematics and telemetry, was used for this study, incorporating numerous muscles and ligaments, including the quadriceps, hamstring, gluteus, iliopsoas, tensor fasciae latae, an adductor muscle groups, and hip capsular ligaments. Ten subjects having a pre-operative degenerative hip were asked to perform gait while under surveillance using a mobile fluoroscopy unit. The hip joint kinematics for ten subjects were initially assessed using in vivo fluoroscopy, and then compared to the predicted kinematics determined using the model. Further evaluations were then conducted varying implanted component position to assess variability.

The fluoroscopic evaluation revealed that 33% of the degenerative hips experienced abnormal hip kinematics known as “hip separation” where the femoral head slides within the acetabulum, resulting in a decrease in contact area. Interestingly, the mathematical model produced similar kinematic profiles, where the femoral head was sliding within the acetabulum (Figure 1).

During swing phase, it was determined that this femoral head sliding (FHS) is caused by hip capsular laxity resulting in reducing joint tension. At the point of maximum velocity of the foot, the momentum of the lower leg becomes too great for capsule to properly constrain the hip, leading to the femoral component pistoning outwards.

During stance phase, kinematics of degenerative hips were similar to kinematics of a THA subject with mal-positioning of the acetabular cup. Further evaluation revealed that if the cup was placed at a position other than its native, anatomical center, abnormal forces and torques acting within the joint lead to the femoral component sliding within the acetabular cup. It was hypothesized that in degenerative hips, similar to THA, the altered center of rotation is a leading influence of FHS (Figure 2).

The theoretical model has now been validated for subjects having a THA and degenerative subjects. The model has successfully derived kinematic patterns similar to subjects evaluated using fluoroscopy. The results in this study revealed that altering the native joint center is the most influential factor leading to FHS, or more commonly known as hip separation. A new module for the mathematical model is being implemented to simulate virtual surgery so that the surgery can pre-operatively plan and then simulate post-operative results.

Figures

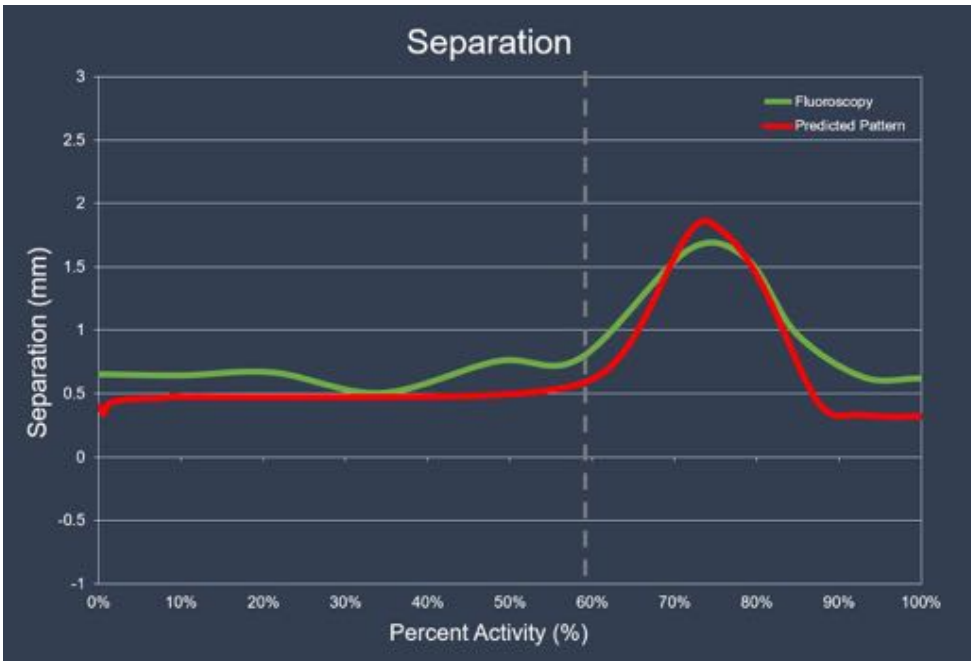

Figure 1

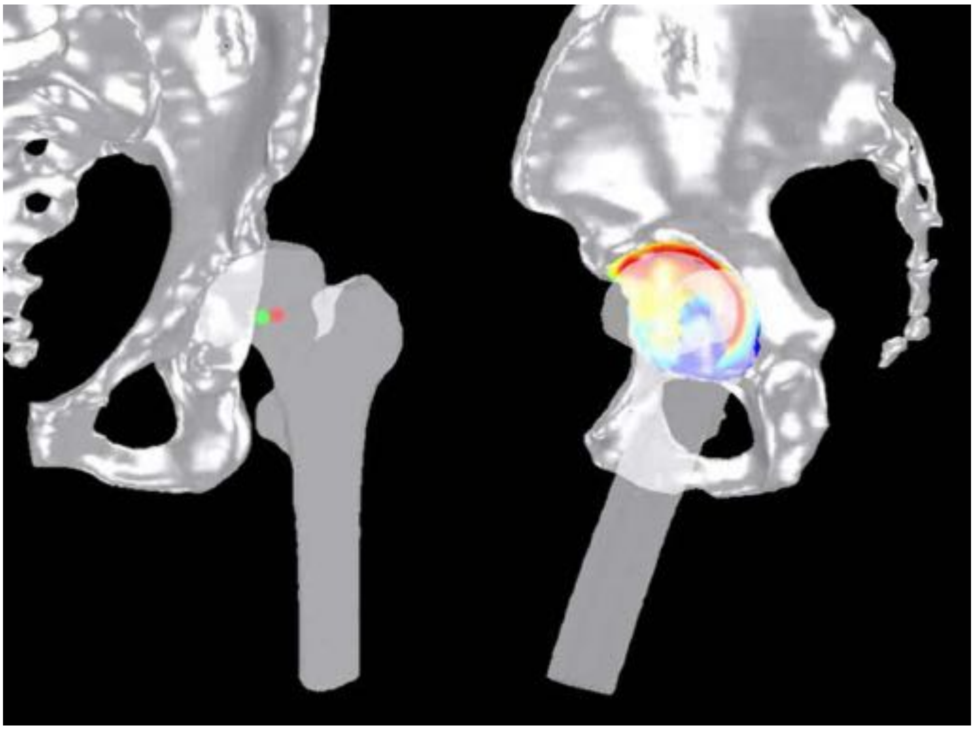

Figure 2

Low Cost Hip Replacement Bearing Mechanics Tool for Device Design and Optimisation: Mathematical Prediction of Separation

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INTRODUCTION:

There is great potential for the use of computational tools within the design and test cycle for joint replacement devices.

The increasing need for stratified treatments that are more relevant to specific patients, and implant testing under more realistic, less idealised, conditions, will progressively increase the pre-clinical experimental testing work load. If the outcomes of experimental tests can be predicted using low cost computational tools, then these tools can be embedded early in the design cycle, e.g. benchmarking various design concepts, optimising component geometrical features and virtually predicting factors affecting the implant performance. . Rapid, predictive tools could also allow population-stratified scenario testing at an early design stage, resulting in devices which are better suited to a patient-specific approach to treatment.

The aim of the current study was to demonstrate the ability of a rapid computational analysis tool to predict the behaviour of a total hip replacement (THR) device, specifically the risk of edge loading due to separation under experimental conditions.

METHODS:

A series of models of a 36mm BIOLOX® Delta THR bearing (DePuy Synthes, Leeds, UK) were generated to match an experimental simulator [1] which included a mediolateral spring to cause lateral head separation due to a simulated mediolateral component misalignment of 4mm (Figure 1). A static, rigid, frictionless model was implemented in Python (PyEL, runtime: ~1m [2]), and results were compared against 1) a critically damped dynamic, rigid, FE model (runtime: ~10h), 2) a critically damped dynamic, rigid, FE model with friction ($\mu = 0.05$, [3]) (runtime: ~10h), and 3) kinematic experimental test data from a hip simulator (ProSim EM13) under matching settings (runtime: ~6h). Outputs recorded were the variation of mediolateral separation and force with time.

RESULTS/DISCUSSION:

The low cost PyEL model successfully replicated experimental trends in maximum separation with changing swing phase load (Figure 2). PyEL provided a good estimate of the high separation values which resulted from lower swing phase loads, but overestimated the separation resulting from higher swing phase loads. The separation verses time curve of the dynamic rigid FE (with and without friction) closely matched that of the PyEL model (Figure 3). Inertia caused a small delay when moving into and out of the cup (peak delay ~0.025s). Therefore there was no substantial advantage to the more costly dynamic finite element models as a predictive design tool for hard-on-hard bearings.

ACKNOWLEDGEMENTS: This study was funded by the UK Engineering and Physical Sciences Research Council (EPSRC); components and CAD files were supplied by DePuy Synthes.

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Figures

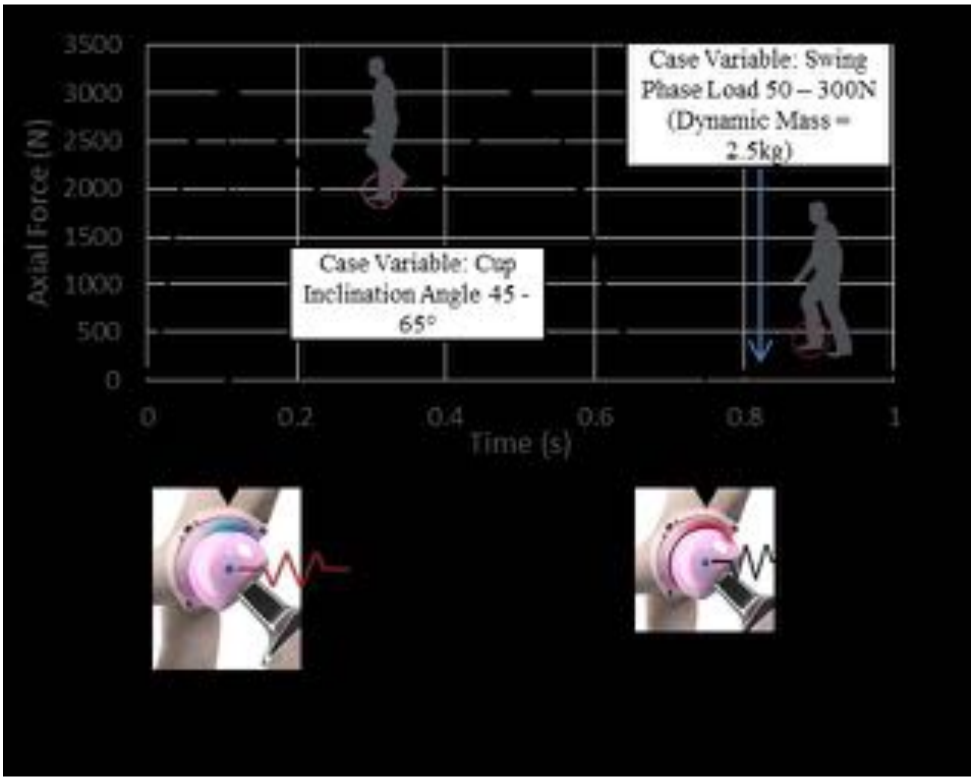

Figure 1

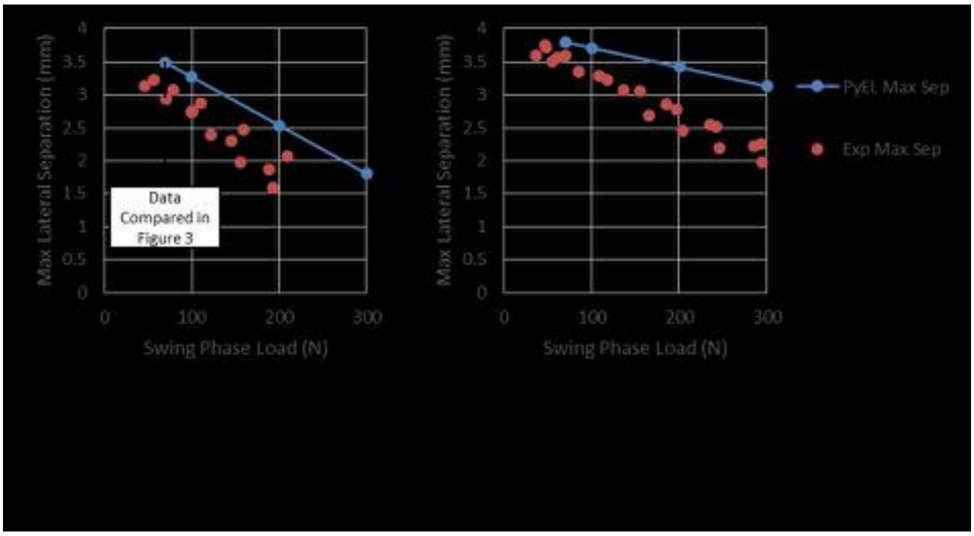

Figure 2

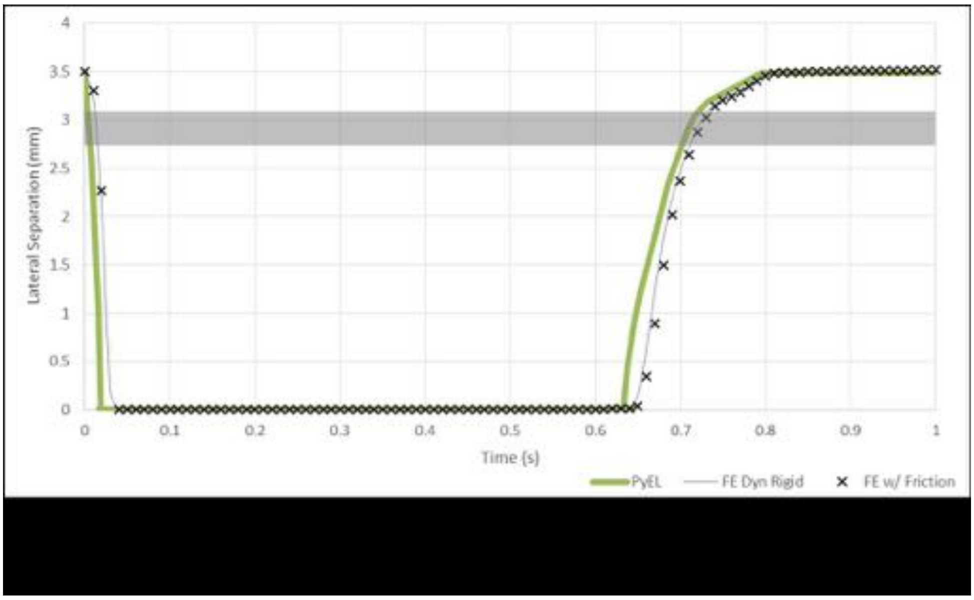

Figure 3

#5764

Forward Solution Modeling to Analyze Normal and Abnormal Knees With Deformities

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Introduction:

Studies have shown anatomical knee variations exist between subjects by gender and ethnicity, and that these morphological differences contribute to demographic-specific kinematic patterns. It is possible that these kinematic variations could increase susceptibility to musculoskeletal pathologies such as osteoarthritis, soft tissue laxity or degenerative deformity. Furthermore, the concept of demographic centric kinematics suggests that these motions should be considered when designing new TKA and developing strategies for implantation. Unfortunately, understanding motion patterns based on specific patient groups, under in vivo conditions, is both difficult and time-consuming A validated forward solution model (FSM) can provide insights on the similar pattern of kinematics and kinetics in various subject groups, further understanding the optimal treatments for each group. The objectives for this study are: (1) to implement the FSM to understand knee kinematics in healthy subjects from having different demographics and (2) to use the same model to investigate the theoretical subjects having abnormal pathology with distinct deformities to gain a better understanding of differences compared to the normal knee.

Methods:

A forward solution mathematical model, validate using fluoroscopy and telemetric TKA, of the knee joint, was implemented assessing kinematic differences between various demographic groups and patients afflicted with pathological conditions. The model controls muscle forces, determining the associated motion using segmented CT scanned bone geometries for male, female, Caucasian, African, and Asian subjects. These demographics and history were known and using the model, kinematics and kinetics were derived for each group. These CT scans featured morphologies, and the geometries were scaled to control for size, initial condition, and soft tissue attachment. Two subjects were assessed within each group to better understand patient-specific variations. Pathological conditions changes were made to the model, altering articulating surface orientation (Varus/Valgus deformity), friction (osteoarthritis), and ligament properties (compromised ligament) to assess the influence of these variabilities affecting the knee.

Results:

The model demonstrated substantive kinematic differences in both condyle translation and axial rotation (Figure 1) with the female subjects experiencing the most overall motion and African subjects experiencing the least. There were, however, substantial variations within each group. Compared to healthy subjects, the model demonstrated that deficient ligament conditions influenced paradoxical motions especially when the PCL was compromised (Figure 2). Increasing friction to simulate osteoarthritis revealed no discernable differences in motions however contact and ligament forces increased up to 40% of bodyweight (BW). The model revealed marginal kinematics differences for alignment deformities with varus deformity exhibiting up to 0.2xBW greater medial condyle contact forces and 0.1xBW lesser lateral contact forces and vice versa for valgus deformity (Figure 3).

Conclusion:

The model revealed differences that kinetics and kinematics may be dependent on subject demographics, in addition to patient pathological conditions. This suggests that demographic differences should be considered in total knee device design and selection although individual variations may suggest advantages of personalized devices. Pathological conditions can also be modeled and used to better understand joint disease and degeneration leading to better-targeted interventions. Such advances in assessment and understanding are greatly facilitated through this mathematical model.

Figures

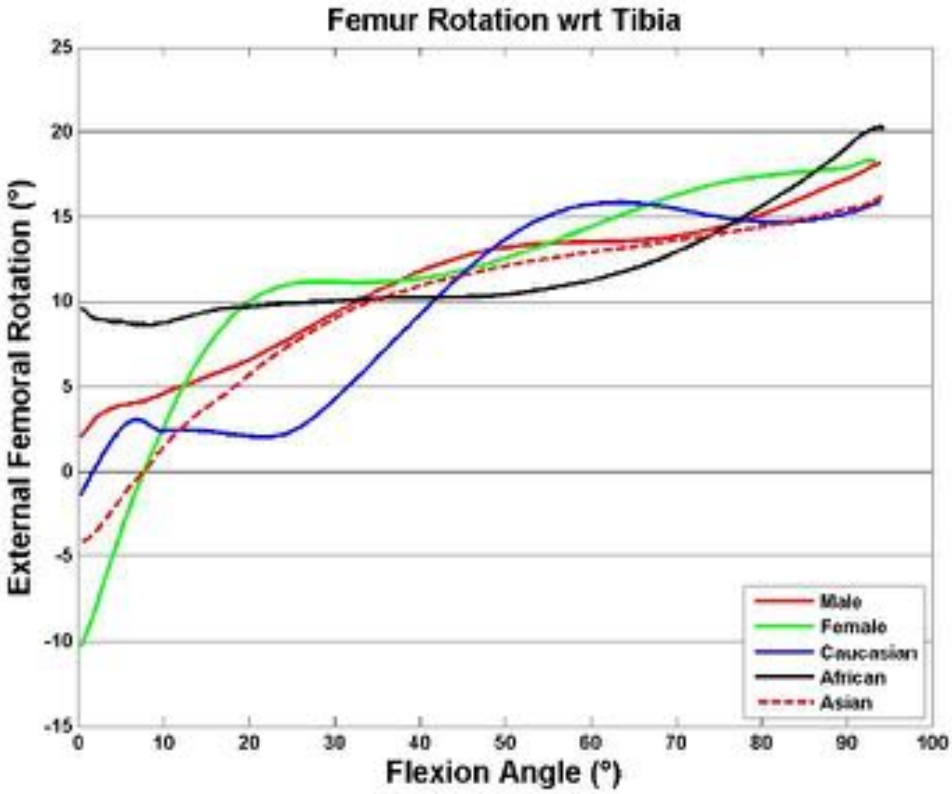

Figure 1: Femur external rotation was compared between demographic groups.

Figure 1

Figure 2: Effects of a knee having a deficient PCL (left) with respect to AP translation, compared to a well-balanced PCL (right).

Figure 2

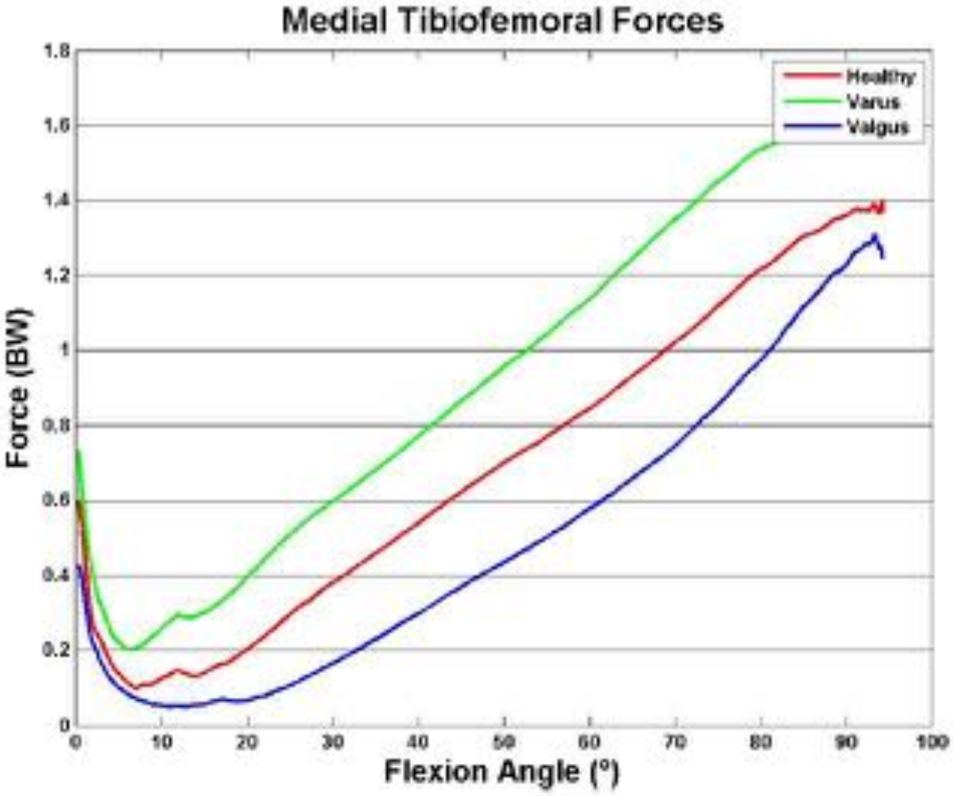

Figure 3:Effects of varus and valgus deformities on medial contact force compare to a healthy knee.

Figure 3

#5994

Comparison of Conventional Versus Kinematic Alignment Technique for Mobile Bearing UKA: An in-Silico Study

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Background: Partial knee replacement aims at preserving bone and cruciate ligaments to ease further revision and provide high knee function. While mobile bearing medial unicompartimental knee replacement (mUKA) aims at restoring the pre-arthritic (or constitutional) limb and knee alignments, their positioning is still recommended to be mechanical, that is the femoral and tibial component being implanted perpendicular to femur and tibial mechanical axes, respectively. This conventional technique of implantation has generated good long-term clinical outcomes, but some complications (residual unexplained proximal tibia pain, tibial plateau fracture, etc.) still remain, and could be the consequence of sub-optimal medial tibia plateau loading. Patient-specific kinematic alignment (KA) technique of implantation is a recent concept where components are positioned by only using intra-articular bony landmarks to closely restore the native articular surface orientation. Such technique of implantation might be clinically beneficial by improving surgical precision and achieving a more physiological knee kinematics and bone loading, and therefore potentially reduce the abovementioned complications and improve patient’s function. Our study aims at comparing the conventional and the kinematic alignment technique for mUKA.

Methods: in-silico study. Cohort of 70 consecutive medial osteoarthritic knee patients scheduled for mUKA having undertook a preoperative CT scan which was segmented to create 3D knee bone models. Conventional and KA mUKA were 3D-planned using Embody software (Embody, London, UK). Implants’ position, and rate of bone undercoverage and implant overhang for the tibial component were compared between the two techniques.

Results: the kinematic femoral components were 3° more valgus oriented, but had similar axial and sagittal orientation compared to the mechanically aligned femoral component. The kinematic tibial components were 3.5° more varus oriented, similarly axially rotated, and 2.8° reduced posterior slope compared to the mechanically aligned tibial component. Kinematic positioning of tibial implant enabled a 20% and 35% reduction of tibial bone undercoverage and tibial implant overhang, respectively, compared to the mechanical positioning.

Discussion/conclusion: KA and mechanical positions of mUKA implants significantly differ form each other. KA positioning of implants enables a better fit of the implant to the bone (reduced overhang, better bone coverage). This better fit, in addition to the more physiologic implant orientation and likely better bone loading, might be beneficial for clinical outcome. Clinical comparison of the 2 techniques of implantation is needed.

#5970

Effects of TKR Alignment, Implant Design and Patient Pre-Operative Alignment on Post-Operative Proximal Tibia Strain

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Introduction

Periprosthetic bone loss after total knee replacement (TKR) is related to the postoperative change in patient varus/valgus alignment [1], and the change in proximal tibial bone strains and strain energy density (SED) from the intact condition to the post-operative state may approximate the remodeling signal [2]. The objective of the current study was to determine this change in bone strain and SED after TKR using different implant designs, surgical alignment philosophies, and patient lower limb alignments, and to determine the relative ranking of these variables.

Methods

A finite element model of a healthy knee was developed in Abaqus/Standard (SIMULIA, Providence, RI) from CT and MRI scans, including proximal tibia, distal femur and cartilages. Apparent density of tibial cortical and cancellous bone was assigned from grayscale (HU) to Young's modulus using established relationships (Fig. 1a) [3]. Two additional finite element models were created by virtually implanting two TKR designs (fixed bearing, cruciate retaining Attune® and Sigma®, DePuy Synthes, Warsaw, IN) to restore a neutral mechanical alignment (Fig. 1a). In addition, the knee was also virtually implanted according to anatomic alignment technique, as estimated from a long-standing x-ray. Each model was positioned at the first ground reaction force peak during gait, according to stereo radiography measurements from the healthy subject [4] and average kinematics from patients with fixed bearing Attune implants [5]. For all models, a compressive load of 2725 N was applied, and two different adduction moments measured during walking for subjects with neutral alignment (27.7 Nm) and varus alignment (39.7 Nm) were used [6]. The changes in von Mises equivalent strain distributions and strain energy density in the tibia were evaluated between natural and implanted cases.

Results

The tibia was divided into four regions (Fig. 2): medial-proximal (MP), lateral-proximal (LP), medial-distal (MD), and lateral-distal (LD). Equivalent strain was reduced by the implant in the proximal regions under the baseplate (MP: -45%/-38% for Attune/Sigma; LP: -65%/-47% for Attune/Sigma) and increased under the stem, especially on the medial side (MD: +77%/+65% for Attune/Sigma) (Fig. 2 and 3). Equivalent strain in the MP region decreased by 45%/38% for Attune/Sigma when compared to the neutral alignment, and by 50%/43% when compared to the varus alignment. Largest SED differences were observed in the cortical bone of the MD region (Fig. 3): Attune/Sigma increased SED by +231%/+335% with respect to the neutral natural case.

Discussion

The largest difference in strain state was created by the procedure overall, while the changes in surgical philosophy (mech v anatomic alignment), patient pre-op alignment (neutral v varus), and implant design were all of approximately the same order. For each implant, the proximal strain is reduced and distal strains are increased near the stem and in the cortical bone, and anatomic alignment reduced the change from the intact state. The largest medial tibial remodeling signal will occur with a varus patient, while lateral remodeling will be driven more by a neutral patient, both coupled with mechanical alignment.

Acknowledgements

Supported in part by NIH R01 EB015497 and DePuy Synthes Products, Inc.

Figures

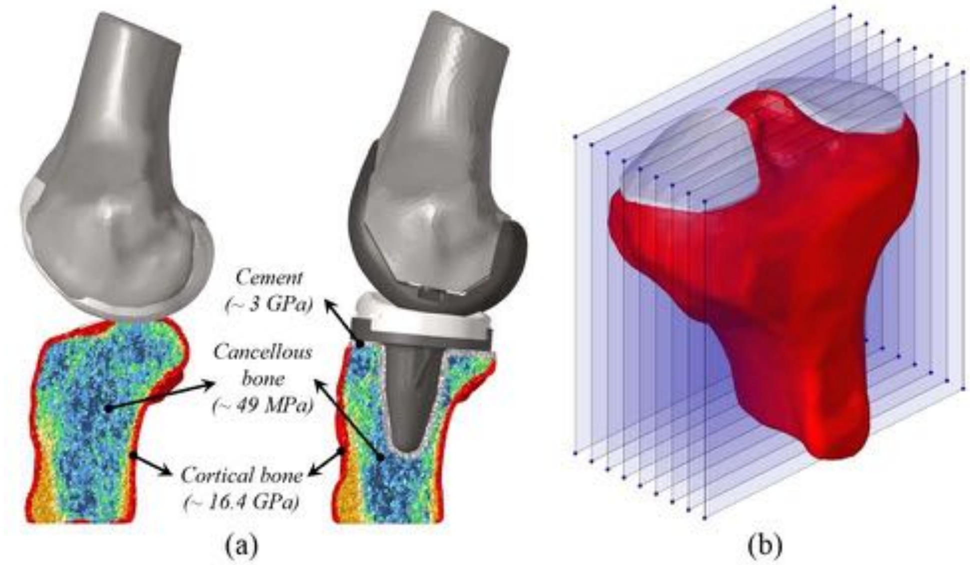

Fig. 1: (a) Young's modulus assignment to the tibial cortical and cancellous bone based on apparent density [2]. (b) Nine sagittal slices used to display strain estimates across the bone (see Fig. 2).

Figure 1

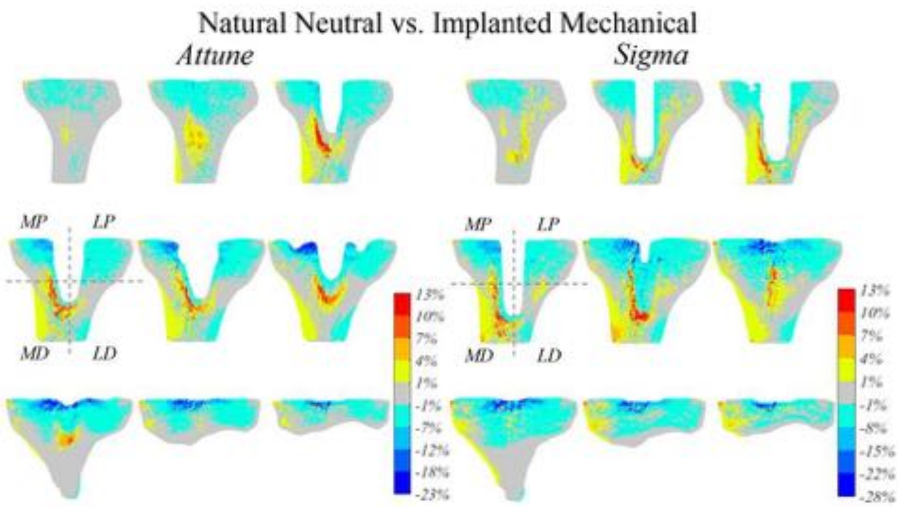

Fig. 2: Contour maps of the *change* in tibial bone strain from the intact condition for the two implants evaluated, assuming a neutral patient alignment and using a mechanical alignment technique.

Figure 2

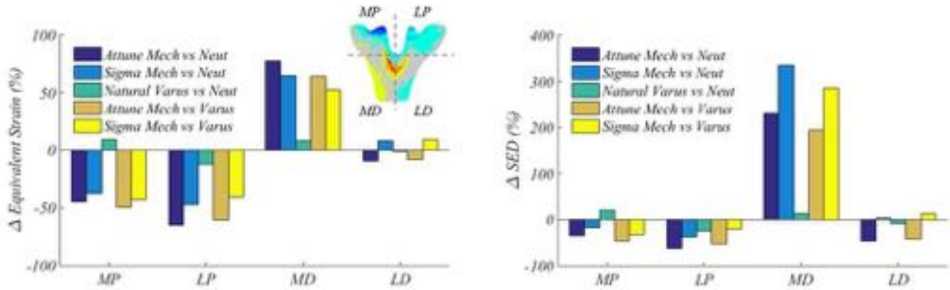

Fig. 3: Graphical representation of the *change* in equivalent strain and SED from the intact to the implanted condition using two implant designs (Attune, Sigma) and two patient Hip-Knee-Ankle alignments (neutral and varus) with mechanical alignment.

Figure 3

#6140

Acetabular Orientation Changes Throughout the Intervention of THA

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Introduction:

Malposition of the acetabular component in total hip arthroplasty (THA) is linked to multiple adverse outcomes. Changes in the sagittal plane position of the pelvis, owing both to patient positioning in the operating room and to altered spinopelvic alignment following surgery, potentially contribute to variation in component position. The dynamics of sagittal plane pelvic position before, during, and after THA have not been defined. We measured the differences in pelvic ratio, a measure of sagittal plane pelvic position, between preoperative, intraoperative, and postoperative anteroposterior (AP) radiographs of patients undergoing THA in the lateral decubitus position.

Methods:

We retrospectively compared the radiographic pelvic ratio among 90 patients undergoing THA. AP radiographs were obtained in the standing position preoperatively and at 6 weeks after surgery; in the lateral decubitus position after trial reduction intraoperatively; and in the supine position in the post anesthesia care unit (PACU). Pelvic ratio was defined as the ratio between the vertical distance from the inferior sacroiliac (SI) joints to the superior pubic symphysis and the horizontal distance between the inferior SI joints (Figure 1). Radlink software was used to determine the pelvic ratio on each radiograph. Changes in apparent cup position based on changes in pelvic ratio were calculated using data from the literature, and a change of at least 10 degrees in acetabular component position was defined as clinically meaningful. Analyses were performed using paired t-tests, with $p<0.05$ defined as significant.

Results:

54% of patients had a change in pelvic ratio large enough to alter the apparent acetabular component anteversion by 10 degrees (49% increased and 6% decreased), and 12% had a change large enough to alter the apparent acetabular component inclination by 10 degrees (12% increased and 0% decreased) when the intraoperative AP radiograph was compared to the preoperative AP radiograph (Figure 2). 36% of patients had a change in pelvic ratio from the preoperative radiograph to the 6 week preoperative radiograph large enough to alter the apparent acetabular component anteversion by 10 degrees (5% increased and 31% decreased), and 8% had a change large enough to alter the apparent acetabular component inclination by 10 degrees (6% increased and 1% decreased).

Discussion:

Changes in the sagittal plane pelvic position between preoperative, intraoperative, and postoperative radiographs occur in a substantial number of patients. These changes correspond to altered functional position of the acetabular component in over half of patients on the intraoperative radiograph and over one third of patients on postoperative radiographs. This variability suggests that intraoperative imaging may be useful for avoiding outliers of component position, and calls into question the feasibility of achieving targeted component positions based on preoperative imaging alone.

Figures

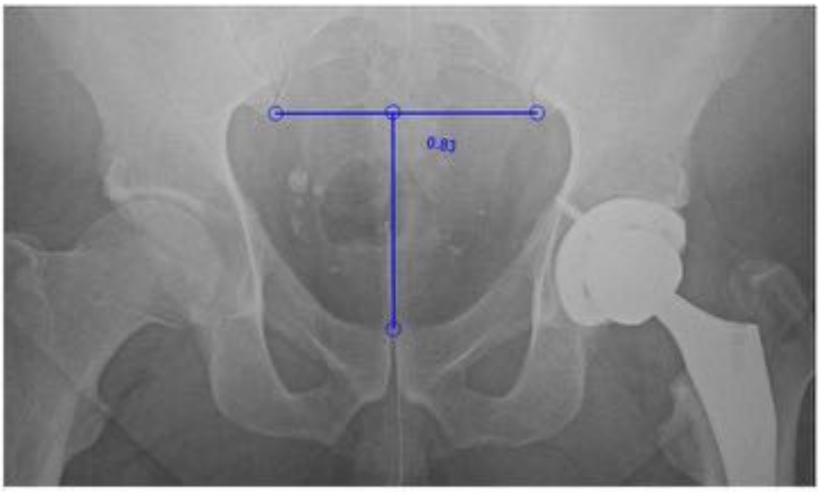

Figure 1. Pelvic ratio is the ratio of the vertical distance between the inferior aspect of the SI joints and the superior symphysis and the horizontal distance between the inferior SI joints.

Figure 1

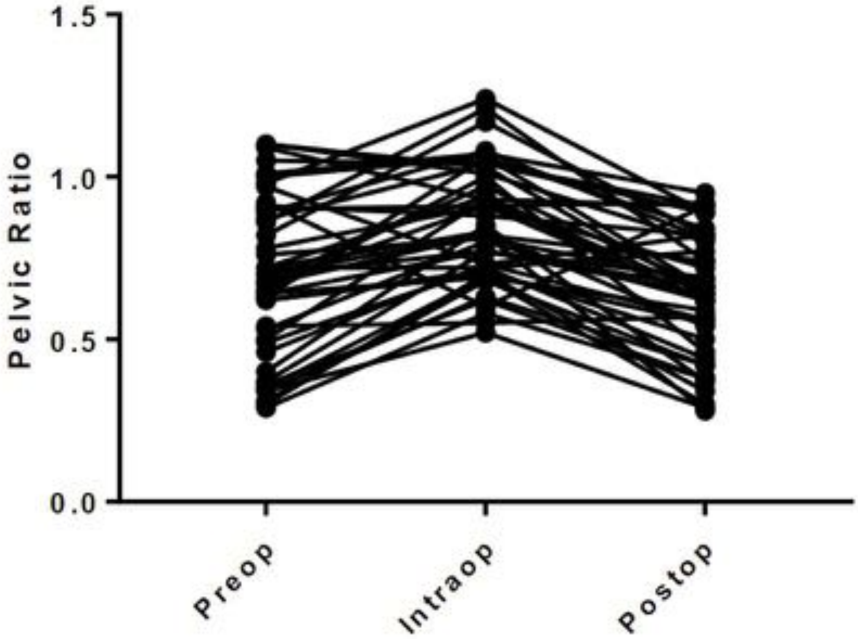

Figure 2. Change in pelvic ratio over time. Postoperative ratio computed at 6 week follow-up visit. Each line represents a single patient.

Figure 2

#6011

Outcomes and Complications of Computer-Assisted Surgery in Total Hip Arthroplasty Utilizing a Nationwide Surgical Database

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Introduction

Although total hip arthroplasty (THA) is an extremely effective procedure, suboptimal outcomes and postoperative complications may occur due to component malposition. One potential solution is the use of computer-assisted surgery (CAS). Despite purported success in optimizing acetabular orientation, there is a paucity of data on whether the current CAS systems improve clinical outcomes.

Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database was utilized to identify patients who underwent primary THA using CAS between 2008 and 2015. Propensity score matching was performed to obtain a control cohort of patients who underwent conventional THA during the same time period. Analysis of covariance (ANCOVA) and multivariate logistic regression were utilized to investigate postoperative outcomes.

Results

We demonstrate that patients receiving THA utilizing CAS had decreased mean lengths of hospital stay (LOS) relative to their conventional THA counterparts (2.08 vs. 3.58 days, respectively; p<0.001) **(Table 2)**, as well as greater odds of requiring a blood transfusion (O.R. 3.31; p<0.001) **(Table 3)** and of being readmitted (O.R. 60.0; p<0.001) within 30 days. Furthermore, patients undergoing conventional THA were more likely to develop pneumonia (O.R. 4.65; p=0.049), a UTI (O.R. 2.57; p=0.009), or sepsis (O.R. 4.90; p=0.013) within 30 days of the primary procedure.

Conclusion

The present study utilized a nationwide database to evaluate the short-term outcomes of computer-assisted surgery (CAS) for primary THA. Patients receiving THA with CAS had shorter LOS, higher odds of requiring blood transfusion, and lower odds of developing complications within 30 days post-operatively compared to patients undergoing conventional THA. Future directions of study include correlation of clinical outcomes with radiographic outcomes, utilization of a database that includes longer-term outcomes, and evaluation of specific implants and CAS systems.

Figures

Table 1. Patient demographics after propensity score matching based on race, BMI, anesthesia type, current smoking status, and admission status.

	Conventional Surgery	Computer-assisted Surgery	p-value
Total Number	1693	1797	
Median age (yrs) (IQR)	65.00 (18)	65.00 (15)	0.952
Sex:			
Female	906 (53.5%)	999 (55.7%)	0.205
Male	787 (46.5%)	796 (44.3%)	
Race:			
White	1520 (89.8%)	1521 (89.8%)	
Black or African-American	151 (8.9%)	141 (8.3%)	
Asian	19 (1.1%)	30 (1.8%)	
Other	3 (0.2%)	2 (0.2%)	0.307
Median BMI (kg/m^2) (IQR)	29.3 (8.53)	28.7 (7.60)	**0.024**
ASA Classification:			
1-No Disturb	60 (3.5%)	98 (5.5%)	
2-Mild Disturb	876 (51.7%)	1060 (59.0%)	
3-Severe Disturb	704 (41.6%)	616 (34.3%)	
4-Life Threatening	53 (3.1%)	22 (1.2%)	**<0.001**
Primary Anesthesia Type:			
General	1,096 (64.9%)	1,307 (72.7%)	
Spinal	396 (23.4%)	260 (14.5%)	
Epidural	185 (10.5%)	187 (10.4%)	
Other	13 (0.8%)	43 (2.4%)	**<0.001**
Charlson Comorbidity Index:			
0	1602 (94.6%)	1724 (95.9%)	
1	77 (4.5%)	66 (3.7%)	
2	4 (0.2%)	3 (0.2%)	
≥3	10 (0.6%)	4 (0.2%)	0.176
Current smoker	226 (13.3%)	203 (11.3%)	0.065
Chronic steroid user	41 (2.4%)	67 (3.7%)	**0.026**
Preoperative blood transfusion (w/i 72 hrs)	0	0	
Open wound or wound infection	9 (0.5%)	5 (0.3%)	0.237
Functional Status:			
Independent	1557 (92.0%)	1741 (96.9%)	
Partially-dependent	127 (7.2%)	52 (2.9%)	
Totally-dependent	9 (0.5%)	4 (0.2%)	**<0.001**
Admission Status:			
Inpatient	1684 (99.5%)	1790 (99.6%)	
Outpatient	9 (0.5%)	7 (0.4%)	0.535

Figure 1

Table 2. Outcomes for patients undergoing primary total hip arthroplasty (THA) with conventional and computer-assisted surgical (CAS) techniques.

	Conventional Surgery	Computer-assisted Surgery	p-value
Mean operative time (min.) (S.E.)[a]	104.7 (5.8)	100.6 (3.5)	0.550
Mean length of stay (days) (S.E.)[a]	3.58 (0.37)	2.08 (0.22)	**<0.001**

[a] Adjusted for BMI, anesthesia type, & chronic steroid use.

Figure 2

Table 3. Complication rates for patients undergoing primary total hip arthroplasty (THA) with conventional and computer-assisted surgical (CAS) techniques.

	p-value	Odds ratio[a,b]	95% C.I. (Lower)	95% C.I. (Upper)
Superficial SSI	0.083	1.948	0.916	4.142
Deep SSI	0.102	2.647	0.825	8.500
Wound disruption	0.725	0.722	0.118	4.415
Pneumonia	**0.049**	0.215	0.046	0.998
Urinary tract infection	**0.009**	0.389	0.191	0.792
Sepsis	**0.013**	0.204	0.058	0.712
Septic shock	0.763	1.320	0.217	8.024
Deep vein thrombosis	0.124	2.327	0.792	6.834
Pulmonary embolism	0.627	0.744	0.225	2.457
Transfusion intraop/postop	**<0.001**	3.308	2.211	4.949
Acute kidney injury	0.682	0.509	0.020	12.829
Cardiac arrest requiring CPR	0.265	2.562	0.490	13.402
Myocardial infarction	0.234	3.827	0.421	34.829
Readmission	**<0.001**	59.987	8.289	434.116

C.I. = confidence interval

[a] Adjusted for BMI, anesthesia type, & chronic steroid use.

[b] Reference is conventional THA group.

Figure 3

#5678

Utility of Mechanical Cup Alignment Device Based on Functional Pelvic Plane in Supine Total Hip Arthroplasty

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Introduction

Pelvic rotation during cup impaction causes excessive cup anteversion should be considered in direct anterior approach total hip arthroplasty (DAA-THA) with supine position. There are two devices based on functional pelvic plane (FPP) referring to horizontal plane through bilateral ASIS during surgery or anatomical pelvic plane (APP) reference to bilateral ASIS and pubis. The purpose of this study was to compare the accuracy of two devices based on FPP or APP in supine THA.

Materials and methods

The subjects of this study were 102 hips of 90 patients who underwent DAA-THA in supine position using a HipPointer based on FPP (FPP group). The other subjects of this study were 29 hips of 27 patients using HipCOMPASS (Lexi, Tokyo) based on APP (APP group). There are no significant differences in age, gender and BMI in the both groups. For the three-dimensional preoperative planning, cup inclination angle 40° of cup inclination angle, 15° of anteversion angle relative to FPP were planned.

HipPointer consist of the body, two adjustable arms and orientation indicator placed to the bilateral ASIS by insertion 2.0mm k-wire through adjustable arms (Fig. 1). To create FPP during surgery, pelvic axially rotation corrected horizontally by pressing bilateral ASIS through the arms of the device. Then, the cup was impacted with the insertion handle parallel to the indicator (Fig. 2). On the other hand, HipCOMPASS® consists of the body, adjustable three arms and indicator, which can input the values by ZedHip® automatically calculated width and height of pelvis, and cup inclination and anteversion angle relative to the APP for each patient. (Fig. 3). After anesthesia, thickness of soft tissue above the bilateral ASIS and pubis were measured and corrected the length of three arms. HipCOMPASS® was pressing on the bilateral ASIS and pubis for creating APP during surgery.

Results

Cup inclination and anteversion angle in FPP group and APP group were 40.3° (33-48°), 40.7° (33-47), and 16.4° (9-26), 17.5° (10-27), respectively. There are no significant differences in cup inclination and anteversion angle in both groups. Nor were there any significant differences in the absolute value errors for cup inclination (FPP; 2.5°±2.1 vs APP; 2.4°±2.0ã€Pï¼0.45) and anteversion angle (FPP; 2.7°±2.4 vs APP; 3.0°±2.0ã€P=0.23).

Discussion

Two devices differs in concept even in use for supine THA. The device based on FPP navigates cup alignment by correction of the pelvic rotation to the horizon. On contrast, the device based on APP navigates cup alignment by following the anatomic pelvic plane during surgery.

Our study showed no differences in cup alignment in both groups. However, advantages of device on FPP were not necessary to consider the thickness of soft tissue above bilateral ASIS and pubis, and not necessary to calculate cup alignment values relative to FPP to APP by computer. New developed mechanical device based on FPP regardless of reference of pubis and computer planning is an easy and useful device compared with the device based on APP.

Figures

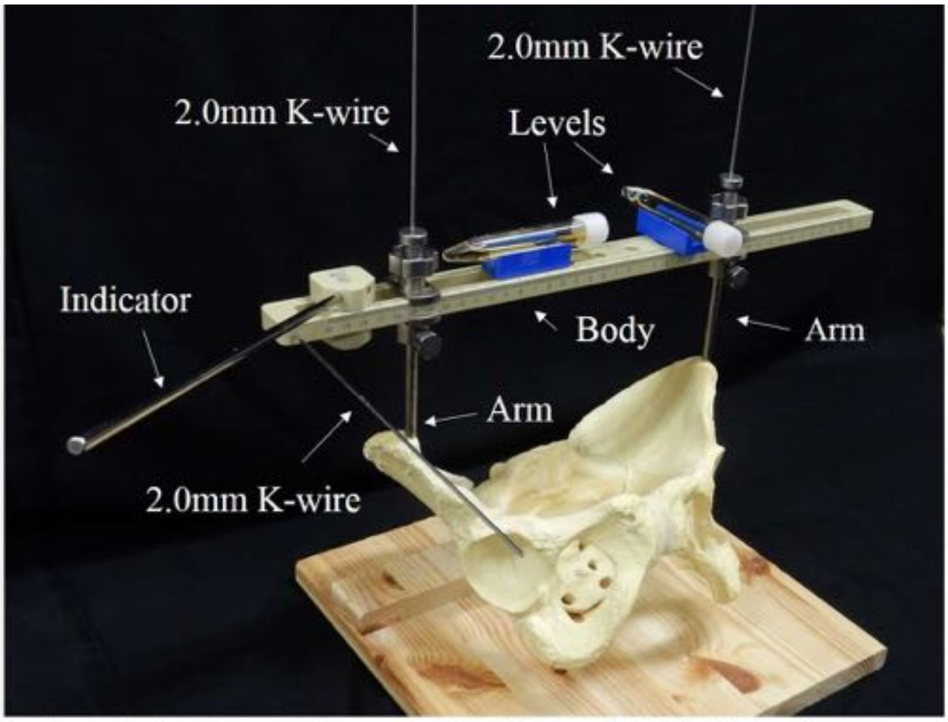

Fig. 1: HipPointer places on the bilateral ASIS through arms and corrects pelvic rotation by 2 perpendicular levels

Figure 1

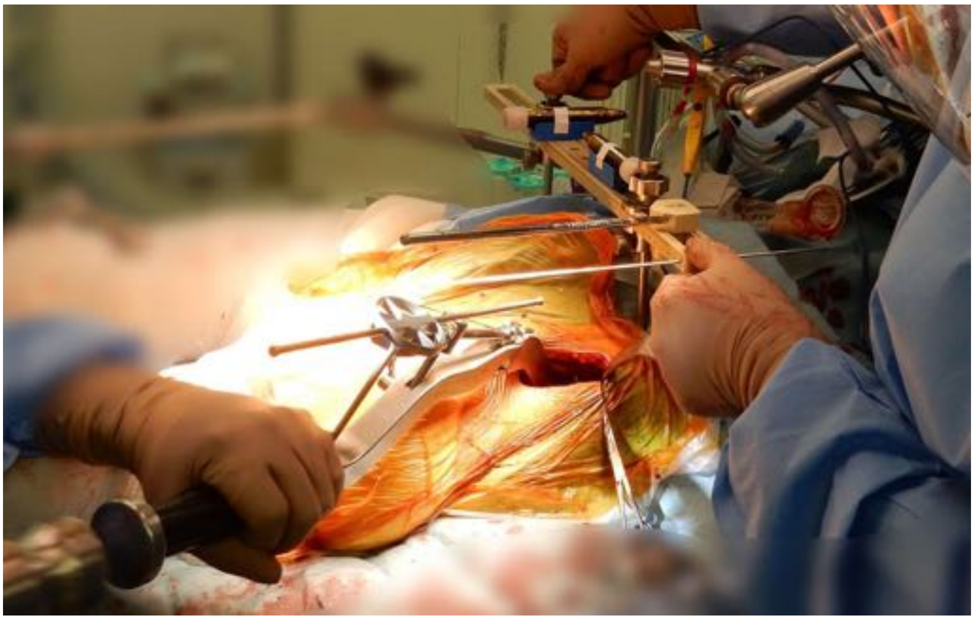

Figure 2

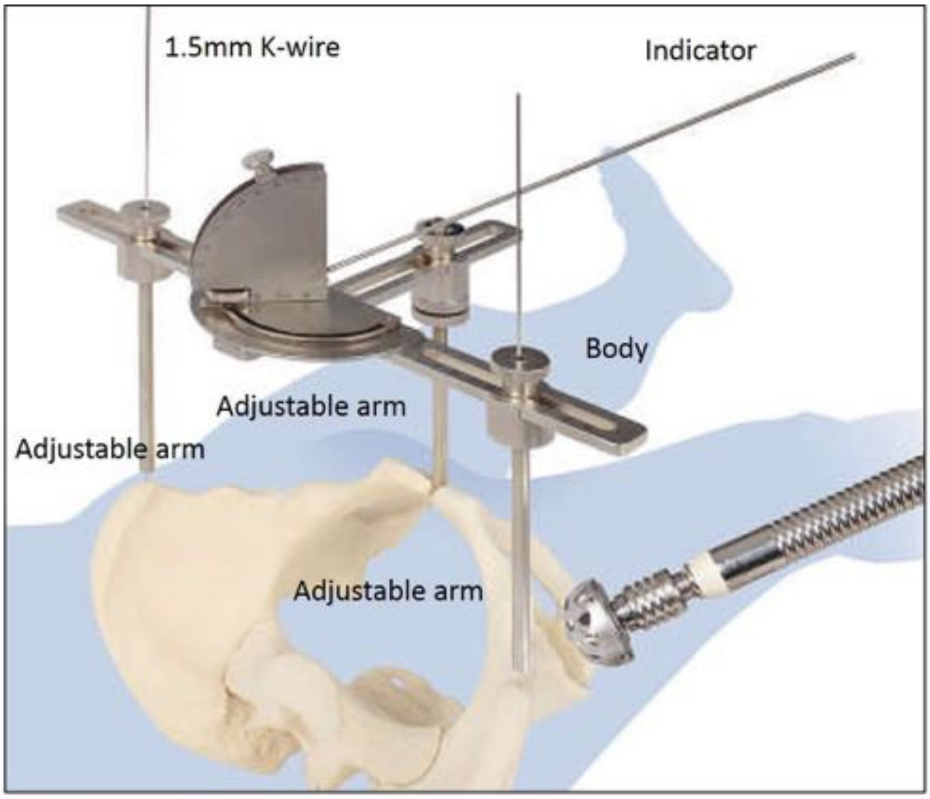

Fig.3: HipCOMPASS® places on the bilateral ASIS and pubis and follows with anatomic pelvic plane for each patients.

Figure 3

#5733

Modifications of the Global Sagittal Alignment After Total Hip Arthroplasty: An EOS Evaluation

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Introduction:

Postural change after THA is a controversial. Investigators only focus on anteroposterior pelvic tilt without considering the lower extremities or the remaining of the spine. This study analyses the post-operative changes of the global sagittal posture using spinal and lower limbs parameters.

Material and Method:

139 patients (primary THA, no spinal or lower limbs pathology) were enrolled for full-body EOS images before and after THA.

We measured pelvic parameters [SS: Sacral Slope, PI: Pelvic Incidence, PT: Pelvic Tilt].

The global posture parameters (SVA, GSA, TPA) were also measured. Sagittal Vertical Angle (SVA) was defined as horizontal distance between the vertical line from C7 and the posterosuperior corner of S1. Global Sagittal Angle (GSA) was defined as the angle between the center of C7 and the middle of the femoral condyles and posterosuperior corner of S1. T1 pelvic angle (TPA) was defined as the angle between the center of T1, the center of the femoral heads and the center of S1.

TPA combines global information of both the spine and the pelvic retroversion, while GSA includes the compensations of the sub-pelvic area with knee flexion.

Patients were categorized into low PI group <45°, 45°< normal PI <65° and high PI group >65°.

Results:

After THA, mean SS decreased from 42.9° (SD 11.7) to 41.6° (SD 11.8) (p=0.002). PT increased from 14.5° (SD 10.4) to 16.4° (SD 10.3) (p<0.001). The overall mean GSA and SVA decreased (p=0.005 and p=0.004 respectively). The TPA change was not significant (p=0.078).

In lower PI group, GSA decreased (5.40 ± 4.95 to 4.29 ± 3.98, p=0.005).SVA also decreased (5.40 ± 4.90 to 4.24 ± 4.11, p=0.038). Postoperative TPA was significantly higher (8.37 ± 10.62 to 9.80 ± 10.68, p=0.048). PT increased (from 5.8 ± 9.84 to 8.13 ± 10.21 (p=0.021)). SS decreased (from 33.38±11.27 to 32.85±11.47) but not significantly.

In standard PI group, SVA decreased (4.22 ± 4.66 to 3.59 ± 4.47, p=0.020). SS decreased (41.74 ± 8.01 to 40.03 ± 8.92, p=0.001). PT increased (14.21 ± 8.19 to 16.28 ± 8.83, p <0.001). Other parameters did not change significantly.

In high PI group, pelvic and global posture parameters don't evolve significantly.

Discussion:

This study confirms significant changes in postural adaptation after THA.

The global analysis points out a tendency for postoperative pelvic extension associated with SVA and GSA decrease.

PI is a key factor (fig 1,2,3).Patients with low PI demonstrate significant adaptations in spine, pelvic and sub-pelvic area after THA. In patients with normal PI, the change in pelvic version is the main variable determining the posture after THA. Patients with high PI are a specific group without significant postural changes.

These considerations regarding the PI influence could expain the controversial data from the literature as the investigators did not analyze their series according to this variable.

Conclusion:

Postural adaptation after THA must be understood using a combined analysis of the pelvic and the global postural parameters.

This study points out the influence of pelvic incidence and the specificity of low PI patients.

Figures

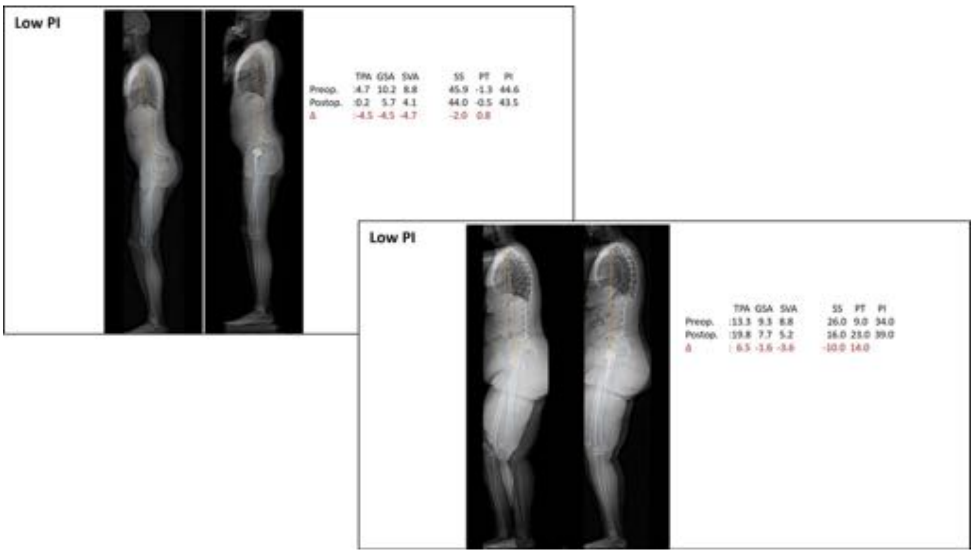

Figure 1

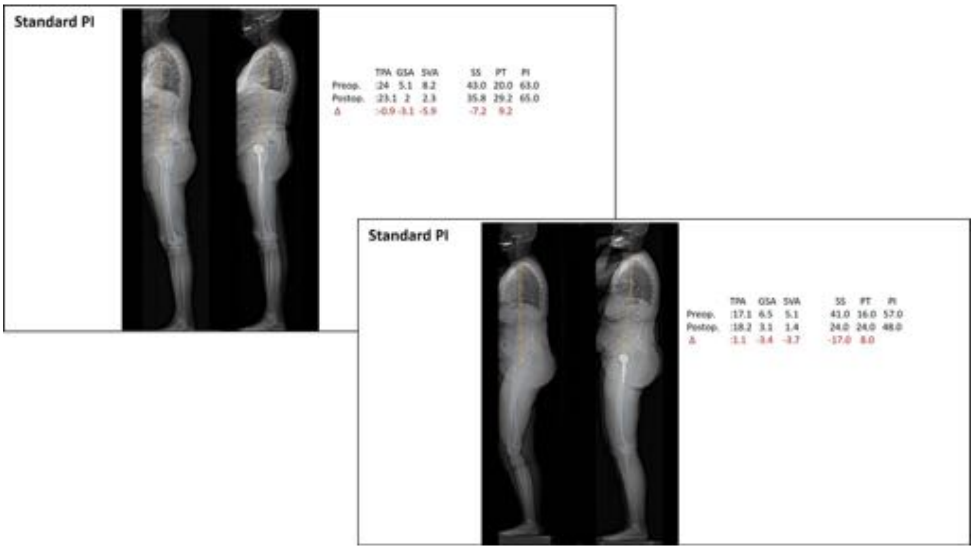

Figure 2

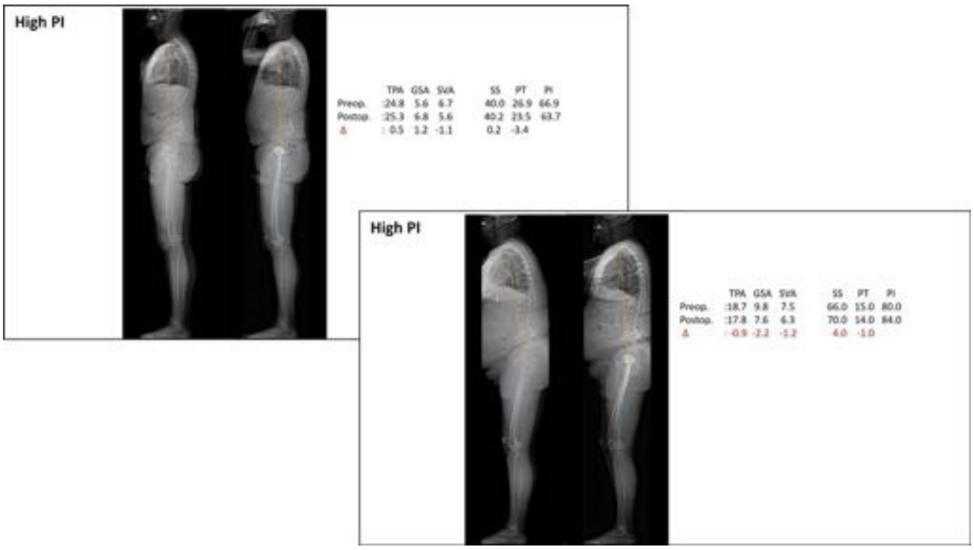

Figure 3

#6059

Accurate Acetabular Cup Placement in Total Hip Arthroplasty Comparison of an Optical Navigation System and Inertial Measurement Unit

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Introduction

Component positioning is of great importance in total hip arthroplasty (THA) and navigation systems can help guide surgeons in the optimal placement of the implants. We report on a newly developed navigation system which employs an inertial measurement unit (IMU) to measure acetabular cup inclination and anteversion.

Aims

To assess the accuracy of the IMU when used for acetabular cup placement and compare this with an established optical navigation system (ONS).

Methods

At the time of acetabular cup impaction, the IMU and ONS were separately mounted on the impactor handle. Cup inclination and anteversion as measured by each device were recorded. Post-operative CTs were acquired for all patients and used to determine the final cup position.

Results

Data were recorded for a total of 100 patients undergoing THA; 51 had a direct anterior approach (DAA) and 49 had a posterior approach (PA).

In the DAA group, the mean difference in IMU versus CT measured cup inclination was -0.7°(range -6 to 8º) compared with mean difference of ONS versus CT of -2° (range -8 to 5º). Mean difference in IMU versus CT measured anteversion was -1.3° (range -10 to 10º) compared with a mean difference of -1.1° (range -23 to 20º) between ONS and CT.

In the PA group, mean difference in IMU versus CT inclination was 1.3º (range -8 to 6º) compared with mean difference between ONS versus CT of 1.6° (range -5 to 7º). Mean difference in anteversion was 3.7° (range -7 to 16º) between IMU and CT and 7.3° (range -3 to 19º) between ONS and CT.

Conclusion

The novel IMU can be used to accurately determine the position of the acetabular cup at the point of impaction, demonstrating comparable accuracy with an established navigation system in the direct anterior approach, and even greater accuracy in the posterior approach.

#5609

Accuracy of Patient Specific Instruments (PSI) in 8 Total Hip Arthroplasties (THA) Through Direct Anterior Approach (DAA): Cadaver Study Results

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Aims

Accurate placement of acetabular and femoral stem components in total hip arthroplasty (THA) is an important factor in the success of the procedure. A variety of free hand or navigated techniques is reported. Survivorship and complications have been shown to be directly related to implant position during THA. The aim of this cadaver study was to assess the accuracy of the placement of the components in THA using patient specific instruments (PSI) in combination with a 3D planning software and the direct anterior approach.

Method

Patient specific instruments (PSI) were developed to guide the surgeon during THA that were 3D printed with their bone models following a 3D software planning protocol (LPH software V2.5.1, Onefit-Medical, Eos Imaging Company, Besancon, France). Acetabular guides: cup , offset and straight reamer handle and impactor, femoral- and chisel guides were used in each THA (Fig. 1). To define anatomic bone landmarks and to generate a 3D model of each hip joint CT scans were performed preoperatively. The planning of component position was done by one surgeon (AZ) preop. Surgery was performed by two experienced surgeons (AZ, SD) on cadaver specimen with 4 hips in two separate series. A total of 8 hip replacements were evaluated pre- and postoperatively using CT-scans of each hip joint to compare planned to achieved results. Mechanical simulations of the guides were carried out to verify that there were no conflicts between the different instruments. To meet the ISO standard 16061: 2015 the compatibility of the instruments with the guides has been checked. Parameters were evaluated in 3D pelvic and femoral planes: center cup position, inclination angle, anteversion angle, cutting height and plan orientation, anteversion angle, flexion/extension angle, varus/valgus angle, anatomical and functional leg length, offset. Acceptance criteria: postop. parameters evaluated must not have a deviation of more than 5 degrees, 2,5 mm according to preop. planning. For every THA the test protocol has been completely realized.

Results

The difference between the preop. and postop. measures in the first series of 4 hips revealed 2 outliers because of fractures of the acetabulum in 2 cases, related to bad cadaver quality. In the second series we found satisfactory results comparing the planned preop and postop component position (Fig. 2). For example difference of leg length showed a mean absolute of 1,58 mm, standard deviation 1,21 mm (min 0,62; max 3,34 mm). Offset revealed a mean absolute of 1,62 mm, standard deviation 0,57 mm (min 1,06; max 2,14 mm) concerning the difference between preop. planning and result postop.

Conclusion

Accurate and safe placement of total hip components in THA, both acetabular cup and stem, performing the direct anterior approach can be achieved using a 3D preoperative planning along with patient specific instruments. The results of the cadaver study tests are promising and that is to be proven in the clinical setting and by application in the future.

Figures

	Trouilloud 4						Trouilloud 5						All cases			
	177001 (right hip)			177002 (left hip)			177003 (right hip)			177004 (left hip)						
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reaming depth of the cup in the acetabulum (mm)	0,19	2,80	2,6	4,20	7,25	3,05	-0,54	0,80	1,34	2,14	4,00	1,86	2,2	0,76	1,34	3,05
Inclination angle of the cup in the acetabulum (°)	48,61	60,14	[illegible]	48,43	46,76	1,67	40,33	40,57	0,24	49,58	52,65	3,07	4,1	5,07	0,24	11,53
Anteversion angle of the cup in the acetabulum (°)	36,92	37,88	[illegible]	16,35	12,14	4,21	23,39	21,89	1,5	24,06	41,4	[illegible]	6,5	7,11	1,50	17,34
Cutting height (verification during study)	Satisfactory			Satisfactory			Satisfactory			Satisfactory						
Cutting plan orientation (verification during study)	Satisfactory			Satisfactory			Satisfactory			Satisfactory						
Anteversion angle of the stem in the femur (°)	25,94	21,87	4,07	22,77	19,01	3,76	10,48	11,06	0,58	26,16	19,97	6,19	3,7	2,51	0,58	6,19
Anterior/posterior position of the stem in the femur (mm)	14,81	15,94	1,13	14,92	13,17	1,75	9,32	11,85	2,53	10,27	12,55	2,28	1,9	0,62	1,13	2,53
Flexion/extension angle of the stem in the femur (°)	4,13	6,05	1,93	7,14	8,29	1,15	6,39	8,43	2,04	8,06	11,74	3,68	2,2	1,08	1,15	3,68
Varus/valgus angle of the stem in the femur (°)	3,1	1,58	1,53	3,47	4,68	0,81	2,4	2,25	0,15	2,76	0,38	2,38	1,2	0,96	0,15	2,38
Anatomical leg length operated side (mm)	446,17	447,15	0,98	448,05	447,43	0,62	371,38	370,98	1,4	375,93	379,27	3,34	1,6	1,21	0,62	3,34
Functional leg length operated side (mm)	816,67	816,71	0,04	819,21	817,28	1,93	680,96	679,75	1,21	682,27	685,31	3,12	1,6	1,29	0,04	3,12
Offset operated side (mm)	60,21	58,08	2,14	60,55	61,61	1,06	83,24	44,42	1,18	47,83	45,75	2,08	1,6	0,57	1,06	2,16

Figure 1

Femoral guide on femoral neck fix with drills

Figure 2

#5933

Can Bone Debris Impede the Seating of Cementless Tibial Trays?

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Introduction: Successful fixation of cementless prostheses requires an intimate and stable interface with supporting bone. Recent investigations of surgical factors affecting the stability of cementless trays show that failure to seat the tray flush with the prepared tibial surface can lead to excessive interface micromotion. Intraoperatively, inadequate seating of tibial trays may be caused by premature end-bearing of fixation pegs press fit into the metaphysis. This may occur if the peg-holes drilled into the metaphysis are too shallow, or if bone debris present within the holes prevents full seating (Figure 1). This study addresses the research question: Can bone debris impede seating of cementless tibial trays?

Methods: Cadaveric matched tibia pairs (6) were dissected free of tissue and mounted in a milling machine. Each proximal metaphysis was precisely milled at a depth of 10mm below the lateral plateau with a posterior slope of 3°. The tibias were then embedded in a resin blocks, sectioned along a plane connecting templated cementless peg hole centers, and reassembled with indexed backing plates and bolts before actual hole drilling. In 6 specimens, peg holes were created with the manufacturer's surgical end mill, while in each contralateral tibia, holes were drilled with a conventional fluted drill. Precision shims were placed on each drill guide to allow full seating of each peg within the fixation holes prior to contact between the tray and the proximal osteotomy.Cementless trays were implanted via a drop-tower instrumented with a force plate (AMTI). Repetitive impact was applied until implant depth became constant. The seating of each tray was tracked using digital image correlation (Dantec). After implantation, the resin-tibia constructs were disassembled, to allow harvesting of bone debris from each peg hole, followed by serial washing to remove fatty marrow and centrifugation to form a compacted pellet for volume measurement. The dimensions of typical bone particles were also measured using stereomicroscopy (ImageJ).

Results: Similar force-displacement curves were observed during implantation in both groups of tibias. In each case, a steep initial rise in implantation resistance occurred with peg engagement (A), followed by a relatively constant resistance during advancement of the pegs (B), terminating in a rapid increase in resistance over the last 1-1.5mm of travel (C) (peg depth at rise in resistance: milling: 10.0±0.2mm; drilling: 12.1±0.2mm, $p<0.01$) (Figure 2). At the conclusion of impaction, tray-plateau separation varied with the method of hole preparation: milling: 3.4±0.11mm; drilling: 1.5±0.07mm, $p<0.01$). This was attributed to the difference in the volume of compacted bone debris found within the peg holes (mill: 0.3±0.02cc; drill: 0.1±0.01cc, $p<0.01$). The aspect ratios of typical bone particles were 0.69 for the milled and 0.80 for the drilled group.

Conclusions

1.Bone debris accumulates within fixation holes machined in the proximal tibia. This can prevent seating of cementless tibial trays.

2. The volume of bone debris generated is influenced by the design of the tool used to create the fixation holes in the proximal tibia.

Figures

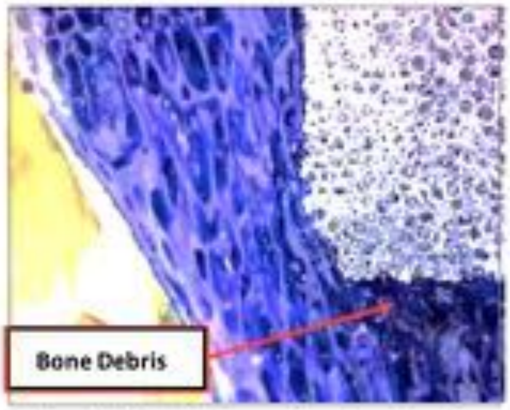

Figure 1. Histologic section showing bone debris beneath a peg of a TM cementless tibial tray

Figure 1

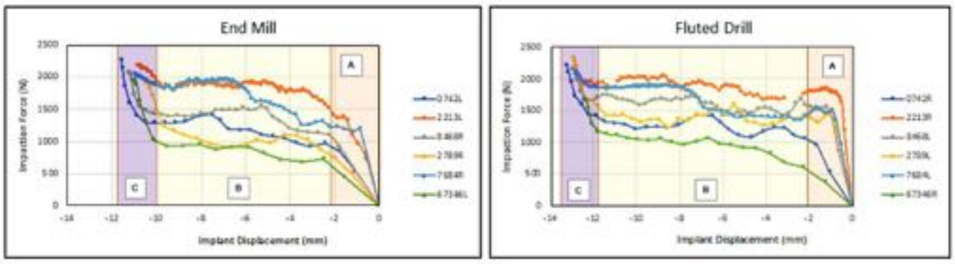

Figure 2. Impaction force and tray displacement curve for both bit types showing the seating level at which increased resistance was encountered.

Figure 2

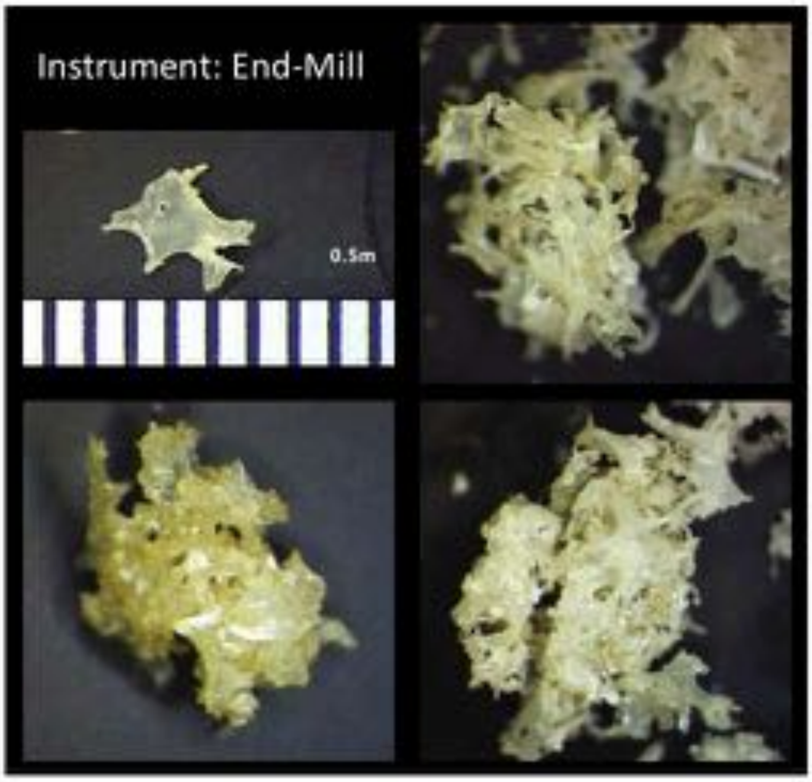

Figure 3. Typical bone particles collected from milled fixation holes

Figure 3

#5985

Does Implant Fixation Affect Patient Satisfaction in Early Follow-Up of Primary Total Knee Arthroplasty?

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Introduction: Improving patient satisfaction following total knee arthroplasty is imperative given that it results in 15% to 20% patient dissatisfaction rates while remaining the gold standard for late-stage osteoarthritis treatment (Scott, Howie, MacDonald, & Biant, 2010). While cementless TKA provides an alternative to the standard cemented TKA, the impact of fixation type on patient satisfaction is not well known. Thus, we compared early postoperative satisfaction between cementless and cemented TKA using the same implant design.

Methods: In a prospective, non-randomized trial, 373 knees in 319 subjects at 10 centers received a single cementless total knee system including cementless metal-backed patellae (Cohort 1) and 146 knees in 133 subjects received a cemented version of the same design (Cohort 2). The new Knee Society Score (KSS-2011), Oxford Knee Score (OKS), and radiographs were collected preoperatively and through 1 year of follow-up.

Results: Skin-to-skin time was lower ($p < 0.0001$) in Cohort 1 than Cohort 2. No differences were observed in adverse event rates or implant survivorship at one year follow-up. At six weeks, statistically significant ($p < 0.05$) differences were identified between the two cohorts in the KSS satisfaction sub-scale, as well as several individual satisfaction questions within the KSS, with the patients in Cohort 1 being more satisfied. This trend continued at six months, with slight variation (Figure 1). The level of patient satisfaction was observed to equalize between the two cohorts at one year postoperative, with statistically significant differences in the level of pain reported on the OKS and the percentage of subjects reporting that their knees always feel normal (Table 1).

Conclusions: In a series of cementless TKAs, we observed shorter operative times and improved early patient satisfaction compared to cemented components. While cementless and cemented fixation provided similar positive outcomes at one year, our results suggest that cementless TKA may provide faster pain relief and return to function, corresponding to increased patient satisfaction in the early postoperative period. Longer term follow up is required to confirm continued implant survivorship and favorable outcomes.

Figures

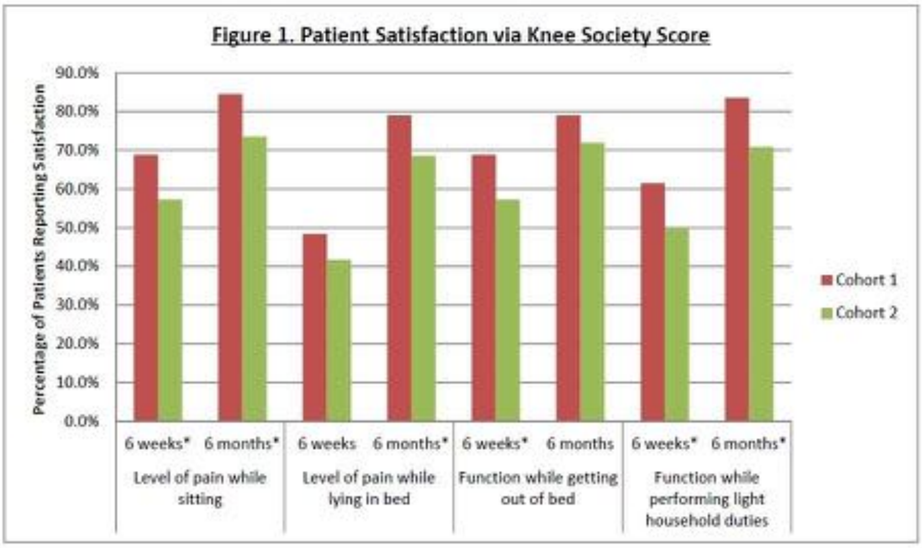

Figure 1

Table 1. Early Differences in Pain and Satisfaction	6 weeks		6 months		1 year	
	Cohort 1	Cohort 2	Cohort 1	Cohort 2	Cohort 1	Cohort 2
KSS satisfaction sub-scale (mean)	*25.91	23.38	31.36	28.88	34.12	32.16
Level of pain while sitting (% satisfied)	*68.9%	57.2%	*84.5%	73.6%	91.0%	86.4%
Level of pain while lying in bed (% satisfied)	48.4%	41.7%	*79.0%	68.6%	87.5%	85.2%
Function while getting out of bed (% satisfied)	*68.9%	57.2%	79.0%	71.9%	87.8%	83.0%
Function while performing light household duties (% satisfied)	*61.5%	49.6%	*83.5%	70.8%	90.1%	81.8%
Knee feels normal (% responding 'Always')	15.8%	12.3%	31.9%	26.4%	*50.0%	34.5%
Describe the level of pain from your knee (% responding 'None' to 'Mild')	52.9%	48.2%	N/A	N/A	*93.1%	84.0%
*Statistically significantly higher						

Figure 2

Enhanced Bone Fixation of TKA Tibial Tray Implants With TiO2 Nanotubes

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Recent clinical data suggest improvement in the fixation of tibia trays for total knee arthroplasty when the trays are additive manufactured with highly porous bone ingrowth structures.[1] Currently, press-fit TKA is far less common than press-fit THA. This is partly because the loads on the relatively flat, porous, bony apposition area of a tibial tray are more demanding than those same porous materials surrounding a hip stem. Even the most advanced additive manufactured (AM) highly porous structures have bone ingrowth limitations clinically as aseptic loosening still remains more common in press-fit TKA vs. THA implants.

Osseointegration and antibacterial properties have been shown *in vitro* and *in vivo* to improve when implants have modified surfaces that have biomimetic nanostructures designed to mimic and interact with biological structures on the nano-scale. Pre-clinical evaluations show that TiO_2 nanotubes (TNT), produced by anodization (Figure 1), on Ti6Al4V surfaces positively enhance the rate at which osseointegration occurs and TNT nano-texturization enhances the antibacterial properties of the implant surface.[2]

In this *in vivo* sheep study, identical Direct Metal laser Sintered (DMLS) highly porous Ti6Al4V specimens with and without TNT surface treatment are compared to sintered bead specimens with plasma sprayed hydroxyapatite-coated surface treatment. Identical DMLS specimens made from CoCrMo were also implanted in sheep tibia bi-cortically (3 per tibia) and in the cancellous bone of the distal femur and proximal tibia (1 per site). Animals were injected with fluorochrome labels at weeks 1, 2 and 3 after surgery to assess the rate of bone integration. The cortical specimens were mechanically tested and processed for PMMA histology and histomorphometry (Figure 2) after 4 or 12 weeks. The cancellous samples were also processed for PMMA histology and histomorphometry. The three types of bone labels were visualized under UV light to examine the rate of new bony integration.

At 4 weeks, a 42% increase in average pull-out shear strength between nanotube treated specimens and non-nanotube treated specimens was shown. A 21% increase in average pull-out shear strength between nanotube treated specimens and hydroxyapatite-coated specimens was shown. At 12 weeks, all specimens had statistically similar pull-out values (Figure 3). Bone labels demonstrated new bone formation into the porous domains on the materials as early as 2 weeks.

A separate *in vivo* study on 8 rabbits infected with methicillin-resistant *Staphylococcus aureus* showed bacterial colonization reduction on the surface of the implants treated with TNT. *In vitro* and *in vivo* evidence suggests that nanoscale surfaces have an antibacterial effect due to surface energy changes that reduce the ability of bacteria to adhere.

These *in vivo* studies show that TNT on highly porous AM specimens made from Ti6Al4V enhances new bone integration and also reduce microbial attachment.

1. Miller, A. J., et al. Results of cemented vs cementless primary total knee arthroplasty using the same implant design. J Arthroplasty 2018; 33: 1089-1093.

2. Su, E. P., et al., Effects of titanium nanotubes on the osseointegration, cell differentiation, mineralisation and antibacterial properties of orthopaedic implant surfaces. Bone Joint J. 2018; 100-B (1 Supple A): 9-16.

Figures

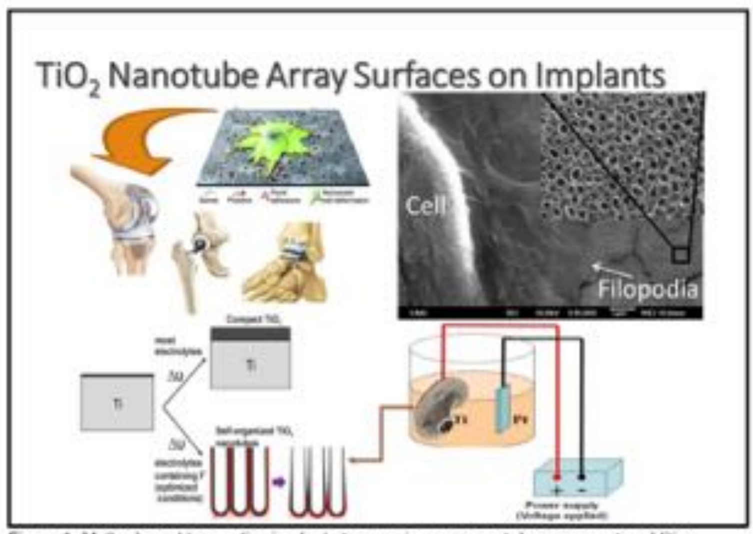

Figure 1. Method used to anodize implants to superimpose nanotube arrays onto additive manufactured Ti6Al4V Tibial Tray components.

Figure 1

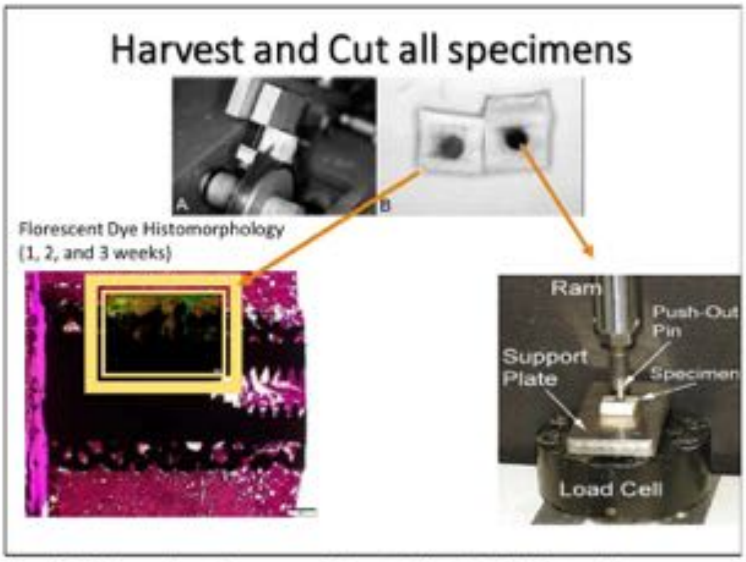

Figure 2. After harvest, specimens are cut in bone, half is sliced into histomorphology specimens, half are used for push out specimens.

Figure 2

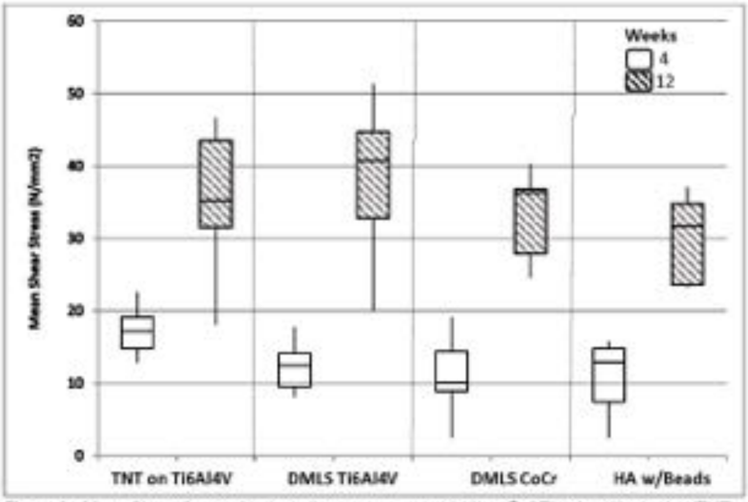

Figure 3. Mean Shear Stress (push out/bone contact area) N/mm^2 of Titanium Nanotube (TNT) treated and non-nanotube treated porous DMLS Ti6Al4V, DMLS porous CoCrMo, and HA on CoCrMo sintered beads after 4 weeks and 12 weeks *in vivo*.

Figure 3

#5981

Loading History Impacts Stability Evaluation of Cementless Knees

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INTRODUCTION

Ensuring sufficient primary stability of cementless tibial trays in total knee arthroplasty remains an important design goal. Various benchtop and in vitro test methods have been used to characterize fixation. However, the influence of load history on measurements or predictions of stability has not been characterized. The goal of this study was to utilize a combined experimental and computational approach to assess the extent to which load history in cementless stability testing impacts key results.

METHODS

Both benchtop testing and finite element (FE) analysis involved a single symmetric tibial tray fixed into bone foam, using preparation consistent with cementless trays. Uniaxial loading was applied at three locations on the articular surface, relative to the fixation features of the tray: (1) posterior to the medial fixation peg (*load-PM*); (2) approximately centered on the medial fixation peg (*load-MC*); and (3) posterior to the lateral fixation peg (*load-PL*). Two loading histories were tested and modeled, each on new foam samples: 3000 cycles each at location *load-MC*, *load-PM*, and *load-PL*; and (reversed order) 3000 cycles each at locations *load-PL*, *load-PM*, and *load-MC*. All loads were 1000N. The tray was positioned 1mm proud of the bone surface, to represent a worst case reconstruction that may result from poor bone preparation. Tray and foam motion was measured using digital image correlation, at five specific peripheral tray locations: anteriorlateral (AM), anteriorcentral (AC), anteriormedial (AM), posteriorlateral (PL), and posteriormedial (PM). An FE model was constructed analogous to the physical test setup. To account for preconditioning in the model, inelastic effects were incorporated into the response of the polyethylene and the foam, based on measured yield properties of the constituent materials.

RESULTS

Foam damage was evident in permanent, non-recovered displacement of the tray (Fig. 2a). Tray motion demonstrated history dependence, with a significant decrease in cycle-to-cycle motion between the first and final cycle (Fig. 2b). Tray response was highly dependent on the load location (Fig. 3a), with peak subsidence (posteriormedial) and liftoff (anteriorlateral) occurring for posteriormedial loading. Model predictions (Fig. 3b) closely mirrored this behavior. When the loading order was reversed (*load-PL*, then *load-PM*, then *load-CM*), posterior medial loading remained worst case between the three load locations (data not shown here). However, there was an approximate 50% decrease in peak micromotion (both subsidence and liftoff).

DISCUSSION

Peak micromotion was observed, both experimentally and computationally, in the posterior-medial region of the tray, in response to loading posterior to the fixation peg on the medial tray. This load location is representative of loading that can occur during various functional activities, and emphasizes the importance of good cortical posteriormedial support. Good agreement was seen between the model and the benchtop test, attributed to proper accounting for the plastic response of the underlying foam. The magnitude of measured and predicted micromotion was significantly impacted by loading history, for the single design considered here. For evaluation of the primary stability of tibial trays in TKA, particularly for comparison between design families, it is thus critical to properly account for dynamic loading.

Figures

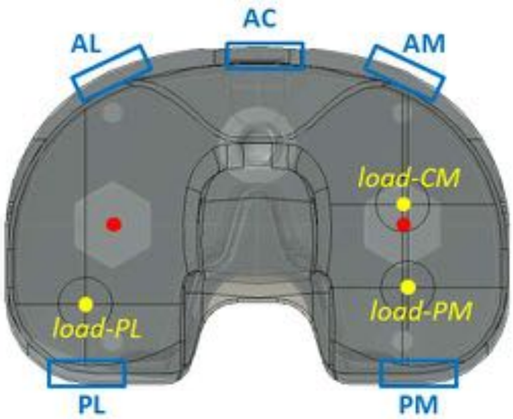

Figure 1: *Representative test and model setup. Load locations are indicated in yellow, relative to the centers of the fixation pegs (red). Regions for measurement and prediction of micromotion are indicated in blue.*

Figure 1

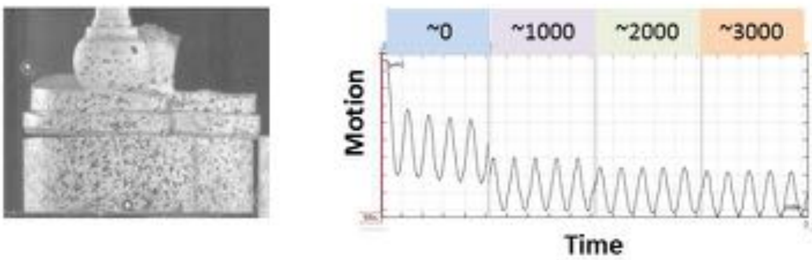

Figure 2. *(left) Permanent tilt in the tray following completion of loading. (right) Representative history dependence of motion during the course of loading, with cycle snapshots at approximately 0 cycles, 1000 cycles, 2000 cycles, and 3000 cycles.*

Figure 2

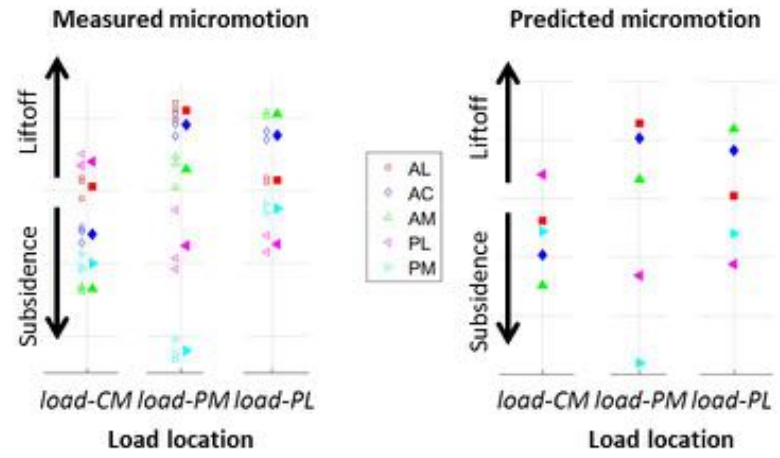

Figure 3. *Experimental measurements (left; individual measurements shown in open symbols, and corresponding average measurements shown in shaded symbols) and computational predictions (right) of tray-bone micromotion for five different locations around the periphery of the tray (AL=anteriorlateral; AC=anteriorcentral; AM=anteriormedial; PL=posteriorlateral; PM=posteriormedial), and for three different load locations.*

Figure 3

Full Activity Micromotion Testing Creates Different Results Than Single Point Loading

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Introduction

Initial stability of cementless implants is critical in order to facilitate the biologic fixation necessary for cementless total knee arthroplasty (TKA). Previous testing to evaluate the micromotion of different cementless implant designs used a single point of loading from a functional activity [1, 2] to characterize the stability of implants, but it is unknown whether this testing truly represents the micromotion that occurs during a full functional activity. The objective of this research is to compare micromotion data from an experiment with a full functional activity to micromotion data from a single point of loading.

Methods

The new loading method was created as a combination of in-vivo loading data, analytical modeling, and robotic loading. The in-vivo data was taken from patients with instrumented implants performing activities of daily living [3]. Analytical modeling was performed using a customized knee modeling software to incorporate different implant designs with the applied in-vivo loading to create an implant specific set of kinetic and kinematic inputs. These inputs were used to drive a robotic simulation that replicate the in-vivo mechanics of the knee during the full functional activity.

Twelve cementless tibial trays, n=6 for two different designs, were tested to determine the micromotion during a full level walking cycle. A cruciate retaining polyethylene insert and mating femoral component were used during the loading. A composite synthetic bone analog was used for this evaluation. Digital image correlation (DIC) was used to measure the micromotion of the tray with respect to the bone analog. A set of mirrors was placed behind the specimen during testing to allow for capturing micromotion data around the entire tibial tray (Figure 1). The total micromotion was calculated by determing the largest 3D distance between two points in that cycle (Figure 2).

The same implant designs in a similar bone analog were tested using a single point of loading to simulate a posterior contact on the tibial articular surface (n=6). The micromotion of these implants with respect to the bone analog was measured using DVRTs.

Results

The maximum total micromotion difference between the two designs was shown to be significant using loading simulating a full activity (Figure 3); no statistically significant differences between the two designs were found when using a single point loading (Figure 3).

Discussion

The predictions of initial stability were heavily dependent upon the methods of applied loading. Full functional activity loading resulted in greater micromotion for both designs as compared to point loading. Further, a statistically significant difference in micromotion response between designs was only found for functional loading. These two factors indicate that functional loading results in both increased predictions of micromotion as well as increased differentiation between designs. It is unknown whether the measurements were influenced by different micromotion measurements systems and is currently being investigated. These findings demonstrate that a full functional dynamic activity loading cycle during micromotion testing is necessary to fully characterize the initial stability of cementless TKA designs and compare between designs.

References

1) Bhimji S, et al; J Arthoplasty (29) 1503-1506, 2014

2) Chong DY, et al; J Biomechanics (43) 1074-1080, 2010

3) Kutzner I, et al; J Biomechanics (43) 2164-2173, 2010

Figures

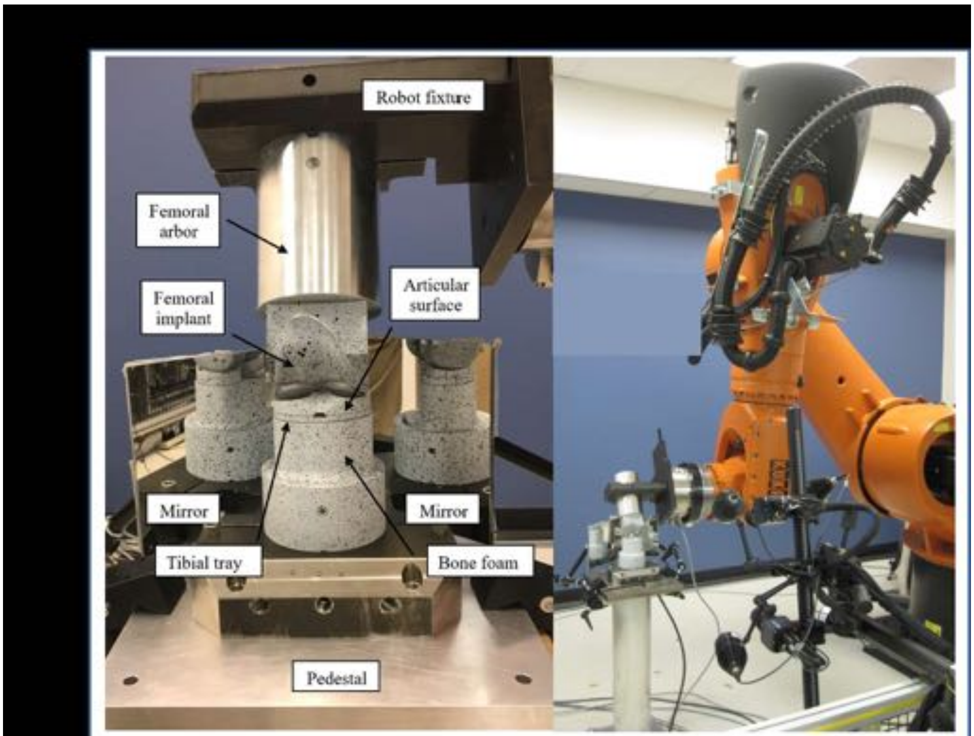

Figure 1: Testing setup (A – Zoomed in view, B – Zoomed out view)

Figure 1

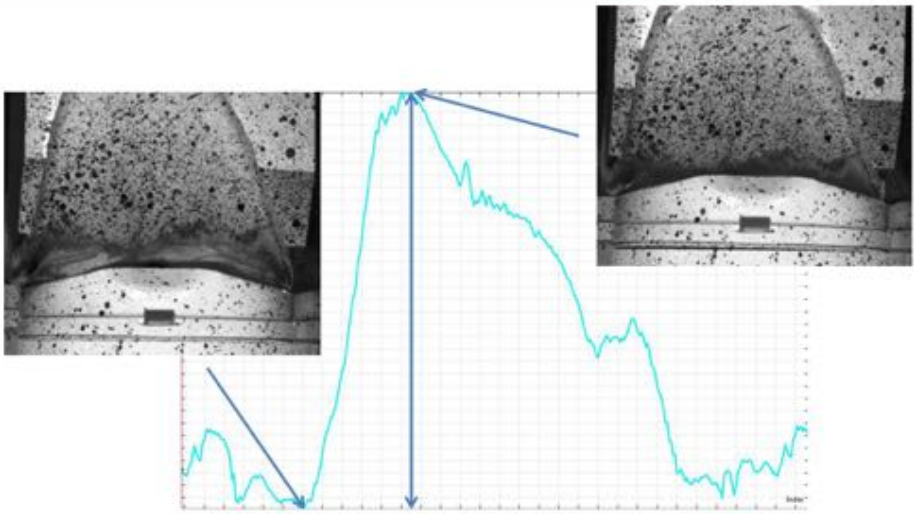

Figure 2: Example of 2D total micromotion calculation (Actual analysis was performed using 3D maximum distance calculations)

Figure 2

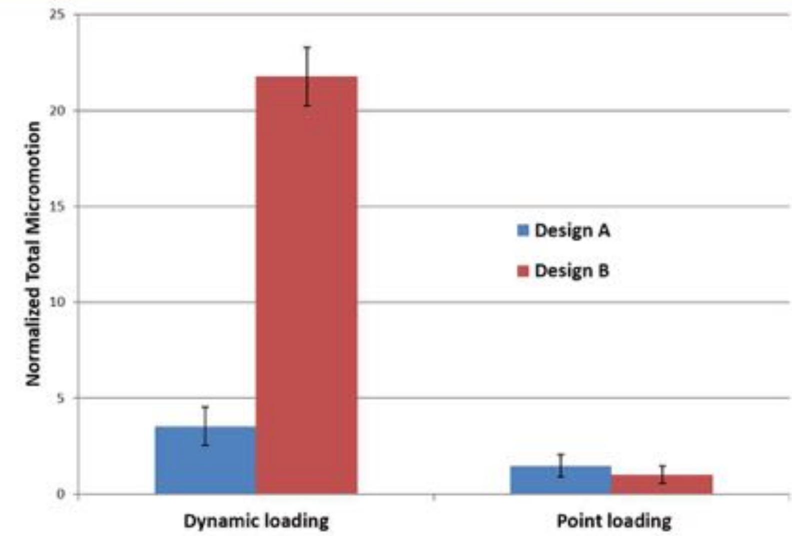

Figure 3: Total micromotion from full activity (dynamic) loading and point loading (normalized to Total micromotion of Design B with point loading, error bars represent standard deviations)

Figure 3

#6081

Effects of Material Model and Implantation on Micromotions Finite Element Analysis of Tibial Component of Primary Total Knee Arthroplasty

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INTRODUCTION: Failed bone ingrowth of the tibial component can result in early loosening, suggested to occur due to high micromotions at the implant interface. These micromotions have been assessed via Finite Element Method (FEM), where the simulation should be realistic to have reliable results. For a realistic simulation adequate activity loads need to be selected, and the implantation process should be simulated prior to the micromotion analysis, to account for intra-surgical damage. Simulating the implantation process requires an adequate plastic material model, where a Von Mises (VM) criterion model or a Crushable Foam Model (CFM) can be used. The purpose of this study is to investigate which material model best predicts bone deformation during implantation, and their effect on subsequent micromotions. Micromotion results were compared to retrieval data on bone ingrowth.

METHODS: An FEM model was created of a tibia (based on CT-scans) implanted with a Zimmer Monoblock trabecular metal tibial component. Four activities were considered: walking, sitting, stair climbing, and cycling. Additionally, four different material models were used: an isotropic linear elastic, a softening VM plastic, an ideal isotropic CFM, and a hardening isotropic CFM. For the three plastic models, an implantation test was performed prior to the micromotion analysis. Finally, the resulting micromotions were compared to an ingrowth threshold of 40 um to estimate the extent of ingrowth.

RESULTS: For the implantation simulations, the VM criterion model showed higher excessive deformations (elements with more than 30% of plastic deformation) when compared to both CFM models (Figure 1). The resulting surface ingrowth was divided by 4 areas: central, medial, and lateral tray, and pegs. Distinct differences were seen between the applied material models for the distribution of ingrowth (Figure 2). The micromotions in the VM model were closest to predict ingrowth, with results remaining mostly within the standard deviation of the retrieval data. The linear elastic model performed the worst, as it over-predicted surface ingrowth in the tray and under-predicted ingrowth in the pegs (Figure 3).

DISCUSSION: The current results stress the importance of including the implant insertion process when analyzing peri-prosthetic micromotions. Previous microCT-based analyses of bone deformation following implantation have shown that during implantation, a 1-2 mm thick layer of highly compressed bone is formed at the implant-bone interface. The current simulations demonstrate that the CFM models were best able to capture this phenomenon, as the VM model tends to overestimate bone damage. The smaller band of plastically deformed bone in the CFM model also resulted in larger shear strains at the implant interface, which in turn may affect bone response and may even promote ingrowth. This raises the question if micromotion is a suitable predictor for bone ingrowth, or whether other mechanical stimuli may need to be involved for obtaining a more realistic simulation of primary stability of press-fit implants.

Figures

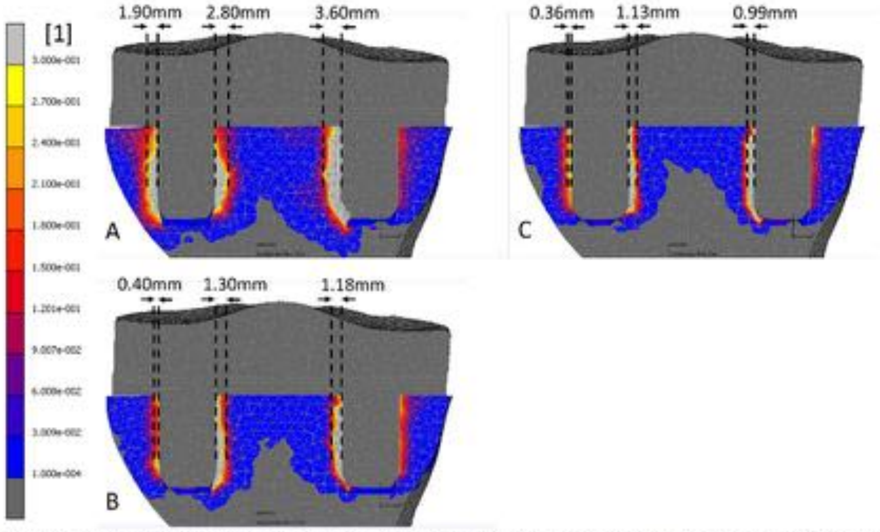

Figure 1: Total equivalent plastic strain after implantation, with areas of excessive deformation is shown in light gray. A) Implantation considering a softening Von Mises criterion (Keyak, 2003). B) Implantation considering a hardening isotropic crushable foam criterion (Kelly, 2013) (hardening function obtained in house). C) Implantation considering an ideal isotropic crushable foam criterion (Kelly, 2013). There was no implantation test for isotropic linear elastic model, as the stresses would be totally unrealistic.

Figure 1

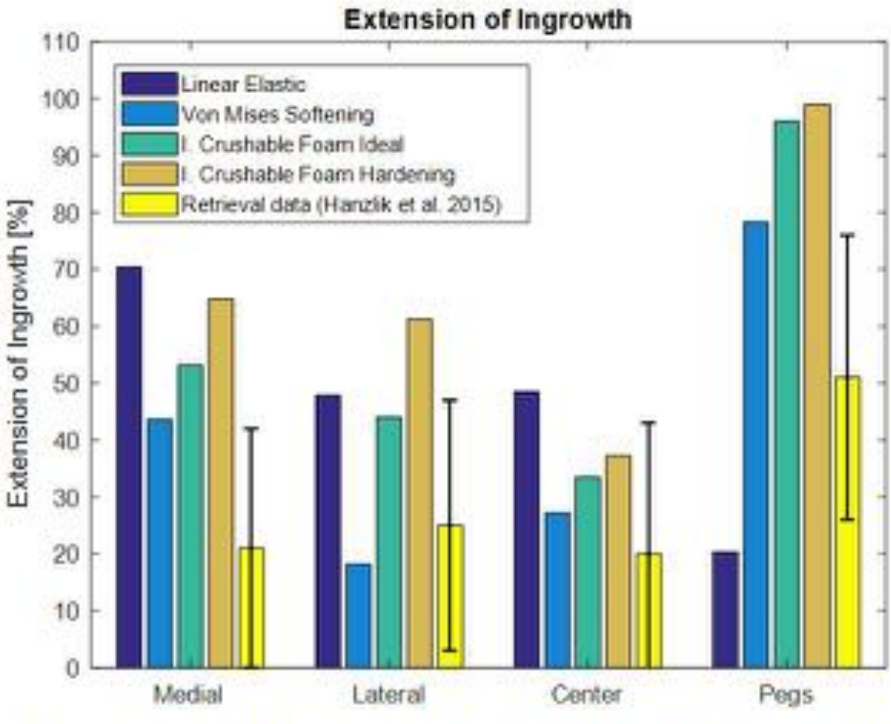

Figure 2: Extent of implant surface ingrowth into bone by material model after considering four activities (walking, stair climbing, sitting, and cycling). The results are also compared to Hanzlik et al. (2015) retrieval data (mean ± SD).

Figure 2

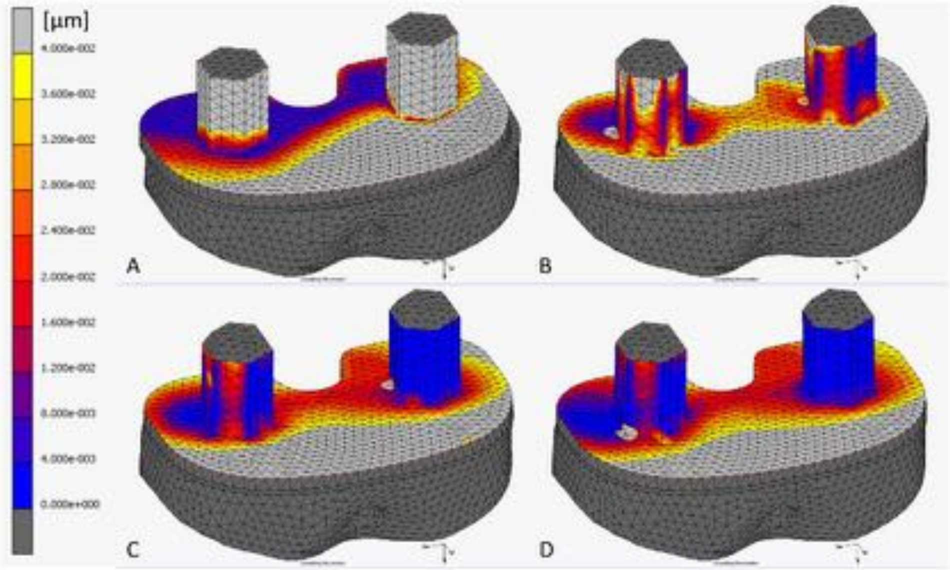

Figure 3: Resulting micromotions of stair climbing activity for every different material model, with areas in light gray showing areas of no ingrowth (beyond threshold of 40µm). A) Isotropic Elastic (Keyak 1997). B) Softening Von Mises (Keyak 2003). C) Hardening Isotropic Crushable foam (Kelly 2013) (hardening function obtained in house). D) Ideal Isotropic Crushable foam (Kelly, 2013).

Figure 3

#5846

Endotoxins That Attached to UHMWPE Particle Surface Induced Higher Level of Inflammatory Cytokines Due to Increased Presence of Particles Around Macrophages in Vitro

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INTRODUCTION

Loosening is concerned to be the major cause of revision in the artificial prosthesis. Wear debris of UHMWPE dispersed into the implant-bone interface are phagocytosed by macrophages releasing inflammatory cytokines such as TNF-α which leads to osteolysis and loosening eventually. It is known that the size and structure [1] as well as attached substances on particle surface such as endotoxin could affect the amount of cytokines released [2]. An *in vivo* study using rat femurs showed that the presence of polyethylene particles around implants could result in accumulation of lipopolysaccharide (LPS) from exogenous sources that may affect bone remodeling around implants [3]. It is also reported that LPS is transported throughout the body with lipoproteins or LPS binding proteins [4] and Circulating LPS may originate from local sites of infection or via bloodborne bacteria [5]. In this study, we evaluated the effects of LPS that attached to UHMWPE particle surface by measuring TNF-α released from macrophages.

MATERIALS AND METHODS

We cultured mouse macrophage cell line RAW 264 with spherical UHMWPE particles (8.7µm and 23µm diameter in average, Mitsui chemicals Co., LTD.) and LDPE particles (3.6µm and 5.8µm diameter in average, Sumitomo Seika Chemicals Co., LTD.) using the Inverse Culture Method for 24 hours before estimating the TNF-α generation by TNF-ALPHA QUANTIKINE ELISA KIT (R&D). Spherical UHMWPE particles (10µm diameter in average, Mitsui chemicals Co., LTD.) with E.coli original LPS (Enzo Life Sciences) attached to them were incubated with cells to see the effects of LPS on the bio-reactivity tests. Bio-reactivity of PE particles was estimated by different methods while culture environment and evaluation method were not standardized. A new index named surface area concentration was proposed in this study, defined as surface area of particles added divided by the surface area of the well to evaluate the bio-reactivity of the particles.

REAULTS AND DISCUSSIONS

Figure 1 shows the TNF-α concentration of different materials and sizes of polyethylene particles. TNF-α concentration was shown to be dose-dependent to the total surface area of particles added regardless of the materials and sizes. Figure 2 shows TNF-α concentration relative to the particle surface area inverse and non-inverse cultured. No significant difference was observed in TNF-α concentration between particles that were attached to LPS and virgin particles in non-inverse culture method. However, when cultured inversely, the effect of LPS became more significant in higher concentration range in which dose-dependent relationship was not observed. The results suggest that saturation may occur caused by size exclusion, production limitation, etc. However, LPS attached to particle surface may alter the production limitation due to increased presence of particles around macrophages.

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Figures

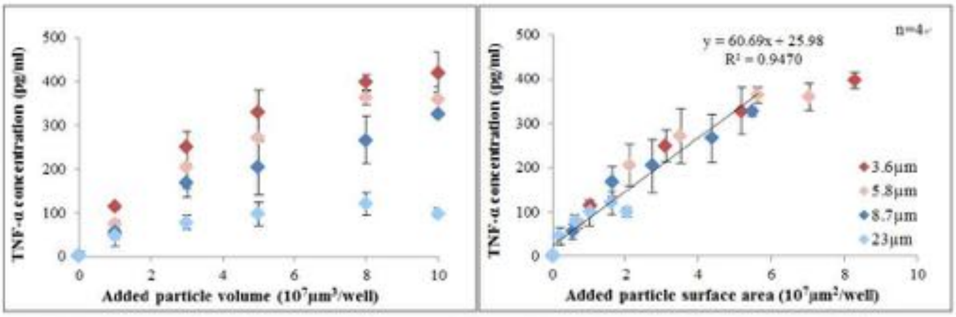

Fig.1 The amount of cytokine generated from macrophages while cultured with virgin PE particles in difference materials and sizes relative to particle surface area rather than particle volume.

Figure 1

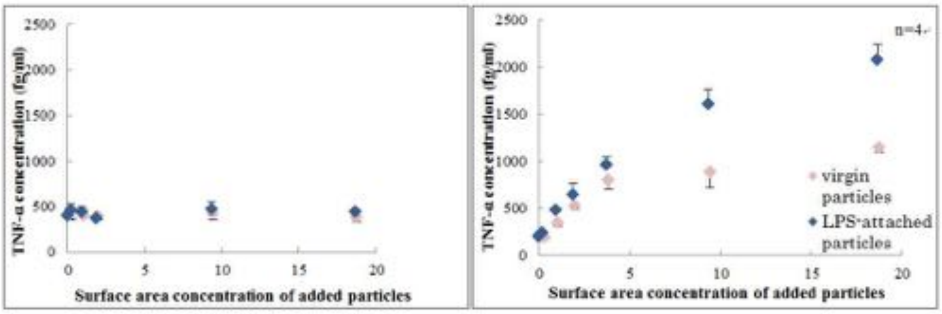

Fig.2 The amount of cytokine generated from macrophages cultured inversely suggests that endotoxins that attached to UHMWPE particle surface induced higher level of inflammatory cytokines due to increased presence of particles around macrophages

Figure 2

#5720

Mechanobiology Based Microscale Study of Influence of Surface Texture Design on Peri-Acetabular Bone Ingrowth

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Introduction

Uncemented porous coated acetabular components have gained more research emphasis in recent years compared to their cemented counterparts, largely owing to the natural biological fixation they offer. Nevertheless, sufficient peri-prosthetic bone ingrowth is essential for long-term fixation of such uncemented acetabular components. The phenomenon of bone ingrowth can be predicted based on mechanoregulatory principles of primary bone fracture healing. It has also been revealed from the literature that the surface texture of implant plays a major role in implant-bone fixation mechanism. A few *in silico* models based on 2-D microscale finite elements (FE) were studied in order to predict the influence of surface texture designs on peri-prosthetic bone ingrowth. However, most of these studies were based on FE models of dental implants. The primary objective of this study, therefore, is to mechanobiologically predict the influence of surface texture on bone-ingrowth in acetabular components considering a novel 3-D mesh-shaped surface texture on the implant.

Materials/Methods

The 3-D microscale model [Fig. 1] of implant-bone interface was developed using CATIA® V5R20 software (Dassault Systèmes, France) and was modelled in ANSYS V15.0 FE software (Ansys Inc., PA, USA) using coupled biphasic poroelastic ten-noded tetrahedral finite elements. The model consists of cast-in mesh textured implant having finely meshed inter-bead spacing. Linear, elastic and isotropic material properties considering Young's modulus of 210 GPa and Poisson's ratio of 0.3 for stainless steel implant were employed in the model. The bone layer was assumed to have a permeability similar to that of immature bone. Boundary of bone was assumed to be rich in Mesenchymal Stem Cells(MSC). The poroelastic material properties in the model were updated iteratively through a tissue differentiation algorithm that works on the principle of mechanotransduction driven by local mechanical stimuli, e.g. hydrostatic pressure and deviatoric strain.

Results

Results indicate that bone ingrowth is inhibited upon increasing the inter-bead spacing and upon decreasing the bead aspect ratio. It has also been observed that there is a predominant influence of bead spacing diameter on the peri-acetabular bone ingrowth. The increase of bead spacing diameter has led to increased bead height which in turn is found to promote higher bone ingrowth with increase in average Young's modulus of newly formed tissue layer.

Conclusion

The present study focussed on the development of a new texture on the implant surface and to study the influence of surface texture on bone-ingrowth in acetabular components. Since there is a promising increase of average Young's modulus of the newly formed tissue layer, it predicts the increase of stiffness of the newly formed tissue. The increase of tissue stiffness reveals that, there is not much inhibition in bone ingrowth after the employment of the acetabular implant. The numerical study based on mechanoregulatory algorithm considering the appropriate mechanical stimuli responsible for bone ingrowth, reveals that, compared to hemispherical beaded surface texture [1], mesh shaped surface texture provides an improved fixation of the acetabular component.

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Figures

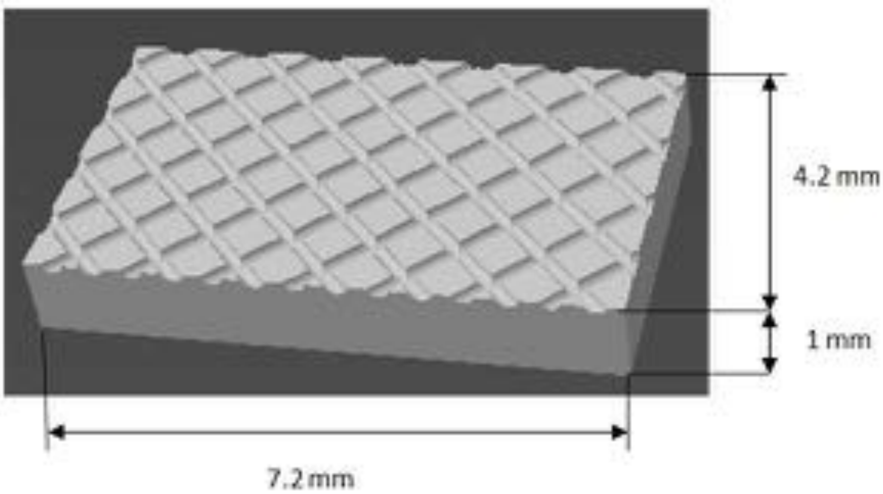

Fig . 1 Isometric view of the implant

Figure 1

#6042

Compounded PEEK-Sintered Silicon Nitride Composite Exhibits Enhanced Osteoconductivity and Resistance to Biofilm Formation

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Introduction: Support of appositional bone ingrowth and resistance to bacterial adhesion and biofilm formation are preferred properties for biomaterials used in spinal fusion surgery. Although polyetheretherketone (PEEK) is a widely used interbody spacer material, it exhibits poor osteoconductive and bacteriostatic properties. In contrast, monolithic silicon nitride (Si_3N_4) has shown enhanced osteogenic and antimicrobial behavior. Therefore, it was hypothesized that incorporation of Si_3N_4 into a PEEK matrix might improve upon PEEK's inherently poor ability to bond with bone and also impart resistance to biofilm formation.

Methods: A PEEK polymer was melted and compounded with three different silicon nitride powders at 15% (by volume, vol.%), including: (i) α-Si_3N_4; (ii) a liquid phase sintered (LPS) β-Si_3N_4; and (iii) a melt-derived SiYAlON mixture. These three ceramic powders exhibited different solubilities, polymorphic structures, and/or chemical compositions. Osteoconductivity was assessed by seeding specimens with 5 x 10^5/ml of SaOS-2 osteosarcoma cells within an osteogenic media for 7 days. Antibacterial behavior was determined by inoculating samples with 1 x 10^7 CFU/ml of *Staphylococcus epidermidis* (*S. epi.*) in a 1 x 10^8/ml brain heart infusion (BHI) agar culture for 24 h. After staining with PureBlu™ Hoechst 33342 or with DAPI and CFDA for SaOS-2 cell adhesion or bacterial presence, respectively, samples were examined with a confocal fluorescence microscope using a 488 nm Krypton/Argon laser source. Images were also acquired using a FEG-SEM in secondary and backscattered modes on gold sputter-coated specimens (~20-30Å). Hydroxyapatite (HAp) deposition was measured using a laser microscope. Raman spectra were collected for samples in backscattering mode using a triple monochromator using a 532 nm excitation source (Nd:YVO_4 diode-pumped solid-state laser).

Results: PEEK composites with 15 vol.% α-Si_3N_4, LPS β-Si_3N_4, or the SiYAlON mixture showed significantly greater SaOS-2 cell proliferation (>600%, $p<0.003$, *cf.*, Fig. 1(a)) and HAp deposition (>100%, $p<0.003$, *cf.*, Fig. 1(b)) relative to monolithic PEEK. The largest increase in cell proliferation was observed with the SiYAlON composite, while the greatest amount of HAp was found on the LPS β-Si_3N_4 composite. Following exposure to *S. epidermidis*, the composite containing the LPS ß-Si_3N_4 powder showed one order of magnitude reduction in adherent live bacteria ($p<0.003$, *cf.*, Fig. 1(c)) as compared to the PEEK monolith. It is interesting to note that the composite containing α-Si_3N_4 exhibited the worst bacterial resistance (*i.e.*, ~100% higher than monolithic PEEK), suggesting that the bacteriostatic effectiveness of Si_3N_4 bioceramics is apparently dependent upon the presence of selective sintering additives, *viz.* yttria and alumina.

Conclusions: The addition of 15 wt.% of specific Si_3N_4 powders to PEEK showed enhanced SaOS-2 cell adhesion, proliferation, and HAp deposition when compared to monolithic PEEK. These same composites also showed resistance to *S. epi.* adhesion and biofilm formation.. Although improvements in osteoconductivity have been previously observed by compounding or coating PEEK with HAp, titanium, or tantalum, these approaches did not provide anti-microbial properties. Compounding PEEK with Si_3N_4 represents a significant advancement due to its ability to provide both improved bone apposition and resistance to biofilm formation.

Figures

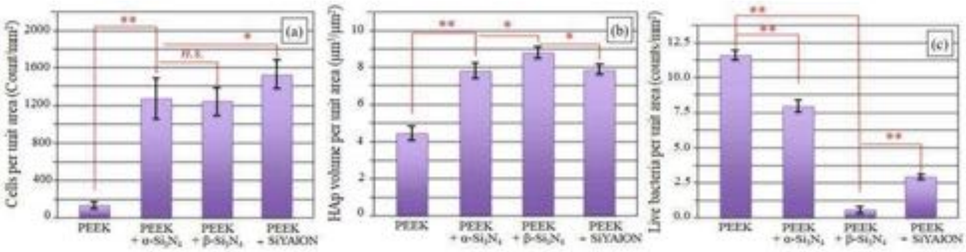

Figure 1

Resistance of a Novel Ceramic Acetabular Cup to Critical Impact Loads

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INTRODUCTION: Unlike current acetabular cups, this novel ceramic cup has a Ti/HA coating which removes the requirement for assembly into a metal shell which avoiding potential chipping/misalignment and reducing wall thickness [Figure 1]. This study examines the resistance of novel thin-walled, direct to bone fixation ceramic cups to critical impact loads.

METHODS: Samples of the smallest (Ø46mm) and largest (Ø70mm) diameter ReCerf^{TM} acetabular cups and corresponding femoral head implants were implanted into Sawbones foam blocks considered representative of pelvic cancellous bone. Two different positional configurations were tested and were considered worst case and the extremes of surgical compromise; P1 simulates the cup fully supported by the acetabulum with a high inclination angle (70°) and a vertical impaction axis (worst case loading near the cup rim) and. P2 simulates the cup implanted with a lower inclination (55°) but with the superior section unsupported by acetabulum bone [Figure 2]. For each size, three acetabular cups were tested in each position. The impact fixture was positioned within a drop weight rig above a bed of sand and ≈22mm of pork belly representative of soft tissues damping effect and the implant components aligned to achieve the defined impact point on the cup [Figure 2]. Lateral falls were tested on all available samples applying impact energy of 140J [1] and 3m/s impact velocity [2]. After the lateral fall test, each sample was tested under impact conditions equivalent to a frontal car crash considering a peak impact force of 5.7kN occurring 40ms from initial contact (able to produce acetabular fracture)[3].

RESULTS: None of the testing simulating a lateral fall produced fracture or any other damage to the ceramic acetabular cup. In 7 of the 12 tests, the impact force was sufficient to fracture the foam block representing the periprosthetic bone. The cups showed a good stability within the blocks, with a maximum recorded cup spinning angle relative to the acetabulum of 4.5Ëš.

Subsequent testing simulating a car crash resulted in the fracture of two samples out of 12, one of the largest and one of the smallest ReCerf^{TM} cups. In both instances, failure occurred very close to the inner edge. Of the remaining 10 samples no cup fractures were observed. All foam acetabulum blocks were severely damaged and 5 blocks fractured. The maximum recorded cup spinning angle following the car crash impact was 5.8Ëš.

SIGNIFICANCE: Extreme testing scenarios presented here are not a regulatory requirement for manufacturers and have not previously been considered for ceramic acetabular components. Fracture is a possible failure mode of ceramics but this testing has proven that modern ceramics can withstand lateral falls and the large majority can withstand subsequent loading equivalent to head on car-crash; loading under which pelvic bone fracture and significant injury is far more likely to occur than implant fracture.

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Figures

Figure 1

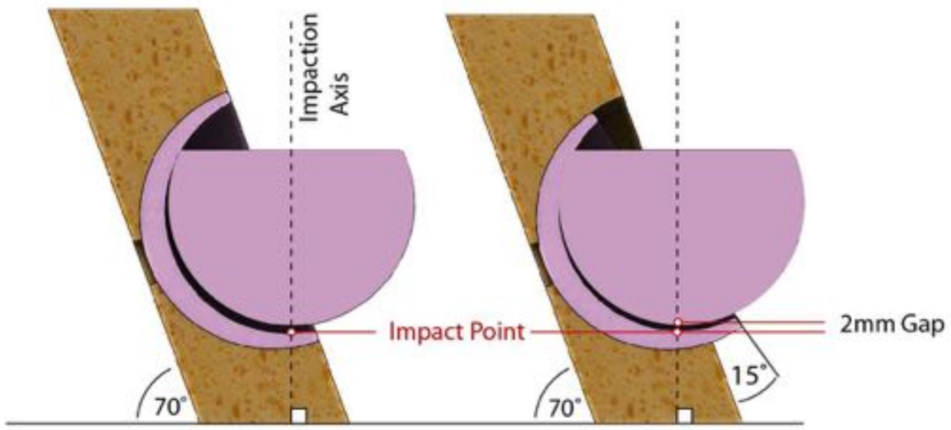

Figure 2

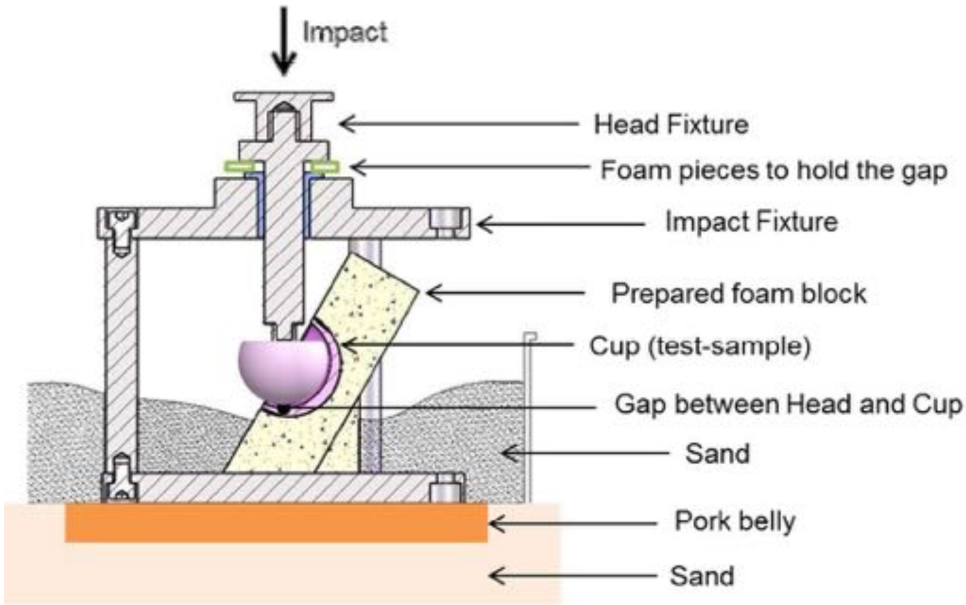
Impact
Head Fixture
Foam pieces to hold the gap
Impact Fixture
Prepared foam block
Cup (test-sample)
Gap between Head and Cup
Sand
Pork belly
Sand

Figure 3

Response Profiles of Circulating Leukocytes and Metal Ions in Patients With a Modular Dual Mobility Hip Implant

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Abstract

Background: The purpose of this clinical study was to evaluate blood metal ion levels and circulating leukocyte profiles in patients with modular dual mobility hip implant (MDM) during postoperative follow-up of up to two-years.

Methods: Forty-nine MDM patients were recruited in a retrospective cohort study with clinical follow-up of up to two-years. Blood concentrations of chromium (Cr), cobalt (Co) and serum cytokines were measured. Flow cytometry quantified subpopulations of leukocytes, including $CD14^+$ and $CD16^+$ monocytes, $CD3^+$ T lymphocytes, $CD19^+$ B lymphocytes, $CD4^+$ Helper T-cells and $CD45^+$RA memory vs. naïve T-cells.

Results: Clinical performances of implants were good during two-years of follow-up. Cr levels were normal in all patients and only detectable in 1 patient (1.4 mg/L, ref $\leq$ 5.0 mg/L). Co levels were mildly elevated in 4 patients at one-year (mean 1.375 mg/L, range 1.2-1.7 mg/L, ref $\leq$ 1.0 mg/L) and in 2 patients at two-year follow-up (both 1.2 mg/L). Interestingly, Co level observed in 3 patients at one-year converted to undetectable at their two-year follow-up. Percentages of B cells, T cells and their subpopulations were within normal levels. There was no increase of $CD16^+$ inflammatory monocytes.

Conclusion: With the recent introduction of MDM systems there is potential for metal ion release from the interface between the acetabular shell and CoCr liner. Clinical results have been good and metal levels undetectable or within acceptable ranges at 1-2 years. There was no evidence of activated immune response, as manifested by constant circulating leukocyte profiles and no increase of $CD16^+$ inflammatory monocytes.

Key Words: Cobalt and Chromium; Metal-on-Metal; MDM System; $CD14^+$ Monocyte; $CD16^+$ Monocytes; Metal Ions

#6101

Pre-Operative Assessment of the Variation in Supine to Standing Pelvic Tilt Using CT and Standing Lateral Imaging

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INTRODUCTION:

Proper component positioning is required for total hip stability and impingement-free range of motion (ROM).[1, 2, 3] Pelvic tilt can change when moving from a supine to standing position.[3] The change if undetected or unaccounted for, may adversely affect post-operative functional ROM and/or standing acetabular cup position.[3, 4] This study was undertaken to determine the change in patient's pre-operative pelvic tilt (PT) when moving from a supine to standing position using Computed Tomography (CT) and standing lateral radiographs.

METHODS:

A consecutive series of 165 osteoarthritic patients underwent supine pre-operative CT in preparation for surgery as shown in Figure 1. In addition, pre-operative standing lateral radiographs were obtained as shown in Figure 2.

Anterior Pelvic Plane (APP) (defined as two anterior superior iliac spines and the pubic tubercle) was measured relative to the Coronal Plane for CTs and radiographs. Pelvic tilt is the angle between the APP and the Coronal Plane. The pelvic tilt angle change from supine to standing was found for each patient. A negative PT angle change indicates posterior tilt, and a positive PT angle change indicates anterior tilt.

RESULTS:

Moving from supine to standing, the pelvis flexed posteriorly in 58.8% cases (97/165, maximum 220), with 13.9% cases (23/165) >100. The graph in Figure 3 depicts the full distribution of change in pelvic tilt angle vs. frequency of occurrence. Anterior flexion occurred in 35.2% cases (58/165, maximum 220), with 9.7% cases (16/165) >100. There was no pelvic tilt change in 6.0% cases (10/165). Overall, 23.6% of the patients had a change in pelvic tilt) >100.

DISCUSSION:

To our knowledge, this is the first study showing the full pelvic tilt change in angle distribution versus frequency of occurrence using preop CT and lateral standing radiograph data. These data varied significantly from past studies using similar imaging: Uemura,[3] more posterior tilt (18.7%, 79/422) and no cases > 100 anterior; Pierrepont,[5] simlar posterior tilt 6% > 130, but 11% anterior > 130. Overall, the data can be used intraoperatively, which may maximize functional ROM.

SIGNIFICANCE:

The change in pelvic tilt from supine to a functional standing position occurs frequently. This study identifies the need to measure and account for this change when positioning hip implants.

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Figures

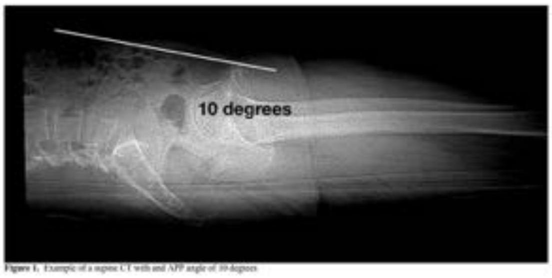

Figure 1. Example of a supine CT with and APP angle of 10 degrees

Figure 1

Figure 2. Example of a standing lateral radiograph with an APP angle of 0.5 degrees

Figure 2

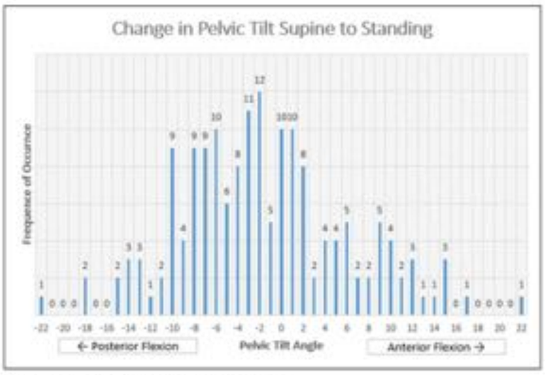

Figure 3: Distribution of the change in pelvic tilt vs. frequency of occurrence

Figure 3

#5812

Quantification of the Dorr Classification System

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INTRODUCTION

The Dorr Bone Classification, devised in 1993 is commonly used to categorize bone types prior to hip reconstruction. The purpose of the present study is to quantify the Dorr classification system using 4 morphologic parameters – morphologic cortical index (MCI), canal-flare index (CFI), canal-bone ratio (CBR), and canal-calcar ratio (CCR).

METHODS

816 hips were reviewed. Demographic data reviewed includes age, sex, and laterality. Each hip was reviewed by 2 separate evaluators for Dorr classification. The MCI, CCR, CBR, and CFI were calculated for each hip on anteroposterior radiographs (Fig 1). One-way ANOVA statistical analysis was used to examine if there are mean differences for each measurement. IRB approval was obtained before collection of data.

RESULTS

The average age of patients was 61 (range 20-96). There were 367 left hips and 449 right hips. The prevalence of Dorr A was 45.8%. The prevalence of Dorr B bone was 38.9% and of Dorr C bone was 15.3%.

One-way ANOVA analysis confirmed the mean differences for each measurement. Measurements of the MCI, CCR, CBR, and CFI were statistically significantly different between the three types of bone. The MCI and CFI were significantly higher in Type A than Type B and higher in Type B than Type C. The CBR and CCR were significantly lower in Type A than Type B and lower in Type B than Type C.

DISCUSSION

To our knowledge, the present study is the first to attempt to quantify the Dorr Bone classification system using MCI, CCR, CBR, and CFI using a large series of patients. Classification of the proximal femur geometry is important as it may play a role in implant fixation for patients undergoing total hip arthroplasty (THA). Furthermore, this information can be used to guide future implant choices.

Figures

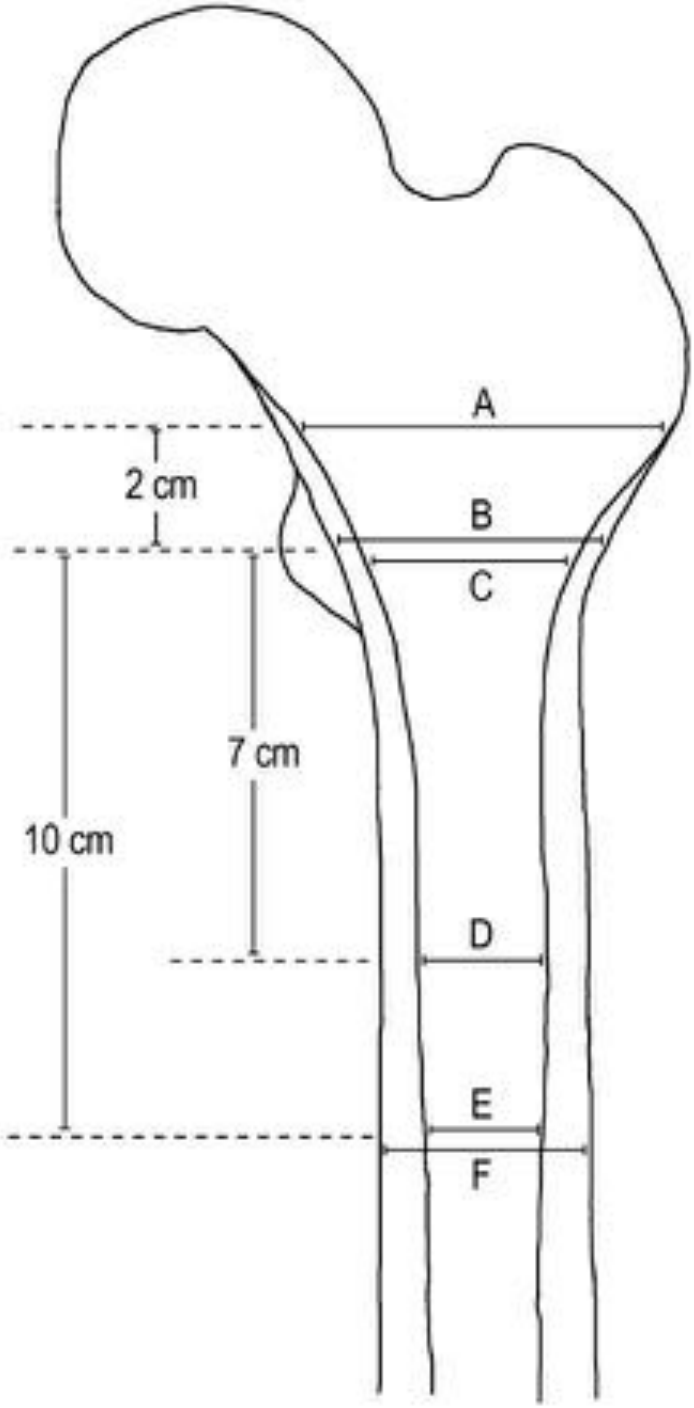

Figure 1

#5953

Native Femoral Version in a Total Hip Replacement Population

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Introduction

Appropriate femoral stem anteversion is an important factor in maintaining stability and maximizing the performance of the bearing after total hip replacement (THR). The anteversion of the native femoral neck has been shown to have a significant effect on the final anteversion of the stem, particularly with a uncemented femoral component. The aim of this study was to quantify the variation in native femoral neck anteversion in a population of patients requiring total hip replacement.

Methods

Pre-operatively, 1215 patients received CT scans as part of their routine planning for THR. Within the 3D planning, each patient's native femoral neck anteversion, measured in relation to the posterior condyles of the knee, was determined. Patients were separated into eight groups based upon gender and age. Males and females were divided by those under 55 years of age, those aged 55 to 64, 65 to 74 and those 75 or older.

Results

The median anteversion in males was 12.7° (-27.1°–45.5°, IQR 6.0°–19.1°), compared to female anteversion of 16.0° (-14.0°–54.5°, IQR 9.7°– 22.4°). These gender differences were statistically significant, $p < 0.0001$. Femoral anteversion in young males (<55) was significantly higher than in older males (>75), p=0.002. This age-related difference approached significance in females, p = 0.06. 14% of patients had extreme anteversion (<0° or >30°)

Conclusions

- The Native femoral neck anteversion in patients requiring THR is widely variable, with a range of over 80°.
- Females have more anteverted femurs than males.
- Femoral anteversion in young males was significantly higher than in older males. This age-related difference approached significance in females.
- Having an understanding of 3D patient morphology can greatly assist in pre-operative planning of THR, as post-op stem anteversion is likely influenced by the anteversion of the native femoral neck.

#5838

Sex Differences in Femoral Morphology in Patients With Developmental Dysplasia of the Hip Undergoing Arthroplasty

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Objectives: For patients with Developmental Dysplasia of the Hip (DDH) who progress to needing total joint arthroplasty it is important to understand the morphology of the femur when planning for and undertaking the surgery, as the surgery is often technically more challenging in patients with DDH on both the femoral and acetabular parts of the procedure[1]. The largest number of male DDH patients with degenerative joint disease previously assessed in a morphological study was 12[2]. In this computed tomography (CT) based morphological study we aimed to assess whether there were any differences in femoral morphology between male and female patients with developmental dysplasia undergoing total hip arthroplasty (THA) in a cohort of 49 male patients, matched to 49 female patients.

Methods: This was a retrospective study of the pre-operative CT scans of all male patients with DDH who underwent THA at two hospitals in Japan between 2006-2017. Propensity score matching was used to match these patients with female patients in our database who had undergone THA during the same period, resulting in 49 male and 49 female patients being matched on age and Crowe classification. The femoral length, anteversion, neck-shaft angle, offset, canal-calcar ratio, canal flare index, lateral centre-edge angle, alpha angle and pelvic incidence were measured for each patient on their pre-operative CT scans.

Results: Significant differences were found in femoral anteversion with a mean male anteversion of 22 Ëš (±14.2), compared to 30Ëš (±15.5), in females (p=0.02, Confidence Interval (C.I.) 1.6 to 14.9, Figure 1), offset, with a mean male offset of 31 mm (±6.2), compared to 29 mm (±6.1) in females, (p=0.04, C.I: 0.2 to 4.8), and femoral length with a mean femoral length of 434 mm in males (±22.2), compared to 407 mm in females (±23.9), (p<0.001, C.I: 19.2 to 34.3, Figure 2). No significant differences between male and female patients were found for the other measurements.

Discussion: This was the first study of this size assessing femoral morphology in male patients with DDH undergoing THA. Significant differences were found between male and female patients in femoral anteversion, length and offset. This should be taken into account when planning and performing THA in these patients. Based on the findings from this study, a more anteverted femoral neck can be expected at the time of surgery in a female patient with DDH undergoing total hip arthroplasty, compared to a male patient.

Figure 1: Femoral neck anteversion (degrees), demonstrating male anteversion to be significantly less than female anteversion (* indicates that *p*<0.05).

Figure 2: Femoral length in mm, demonstrating male femoral length to be significantly more than female femoral length (*** indicates that *p*<0.001).

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Figures

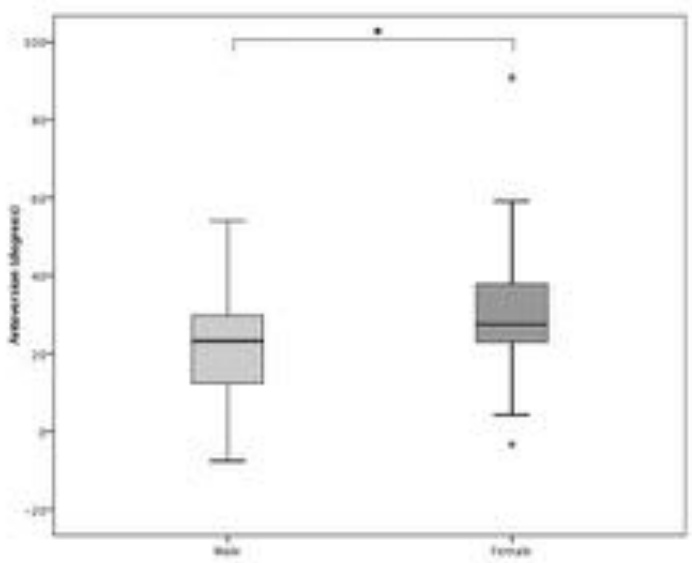

Figure 1

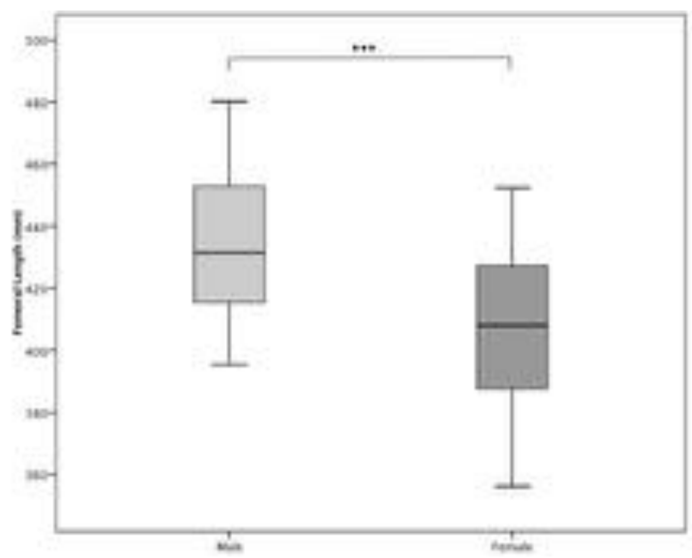

Figure 2

Does Muscle Atrophy Correlate With Muscle Weakness in Unilateral Hip Disease?

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Introduction

Most of patients with unilateral hip disease shows muscle volume atrophy of pelvis and thigh in the affected side because of pain and disuse, resulting in reduced muscle weakness and limping. However, it is unclear how the muscle atrophy correlated with muscle strength in the patient with hip disorders. A previous study have demonstrated that the volume of the gluteus medius correlated with the muscle strength by volumetric measurement using 3 dimensional computed tomography (3D-CT) data, however, muscles influence each other during motions and there is no reports focusing on the relationship between some major muscles of pelvis and thigh including gluteus maximus, gluteus medius, iliopsoas and quadriceps and muscle strength in several hip and knee motions. Therefore, the purpose of the present study is to evaluate the relationship between muscle volumetric atrophy of major muscles of pelvis and thigh and muscle strength in flexion, extension and abduction of hip joints and extension of knee joint before surgery in patients with unilateral hip disease.

Material and Methods

The subjects were 38 patients with unilateral hip osteoarthritis, who underwent hip joint surgery. They all underwent preoperative computed tomography (CT) for preoperative planning. There were 6 males and 32 females with average age 59.5 years old.

Before surgery, isometric muscle strength in hip flexion, hip extension, hip abduction and knee extension were measured using a hand held dynamometer (µTas F-1, ANIMA Japan).

Major muscles including gluteus maximus, gluteus medius, iliopsoas and quadriceps were automatically extracted from the preoperative CT using convolutional neural networks (CNN) and were corrected manually by the experienced surgeon.

The muscle volumetric atrophy ratio was defined as the ratio of muscle volume of the affected side to that of the unaffected side. The muscle weakness ratio was defined as the ratio of muscle strength of the affected side to that of the unaffected side.

The correlation coefficient between the muscle atrophy ratio and the muscle weakness ratio of each muscle were calculated.

Results

The average muscle atrophy ratio was 84.5% (63.5%–108.2%) in gluteus maximus, 86.6% (65.5%–112.1%) in gluteus medius, 81.0% (22.1%–130.8%) in psoas major, and 91.0% (63.8%–127.0%) in quadriceps.

The average muscle strength ratio was 71.5% (0%–137.5%) in hip flexion, 88.1% (18.8%–169.6%) in hip abduction, 78.6% (21.9%–130.1%) in hip extension and 84.3% (13.1%–122.8%) in knee extension.

The correlation coefficient between the muscle atrophy and the ratio of each muscle strength between the affected and unaffected side were shown in Table 1.

Conclusion

In conclusion, the muscle atrophy of gluteus medius muscle, psoas major muscle and quadriceps muscle significantly correlated with the muscle weakness in hip flexion. The muscle atrophy of psoas major muscle and quadriceps muscle also significantly correlated with the muscle weakness in knee extension. There were no significant correlation between the muscle atrophy and the muscle weakness in hip extension and abduction.

Figures

Table 1.

The correlation coefficient between the muscle atrophy and the ratio of each muscle strength between the affected and unaffected side.

muscle atrophy (affected side/unaffected side)	Hip flexion	Hip extension	Hip abdction	Knee extension
gluteus maximus muscle	0.30	0.04	0.05	0.23
gluteus medius muscle	0.34*	0.13	0.06	0.24
psoas major muscle	0.42*	0.10	0.20	0.33*
quadriceps muscle	0.50*	0.26	0.23	0.61*

*: $p<0.01$

Figure 1

#5983

Iliopsoas Pressures After Standard Total Hip Replacement

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INTRODUCTION: Around 13% of patients report persistent groin pain after total hip replacement (THR). Although the etiology is multi-factorial, one commonly cited source of groin pain is localized overload of the ilio-psoas complex as it wraps around the femoral head (Iliopsoas impingement (IPI)). This proposed etiology may explain why the incidence of groin pain increases in THR patients with large-diameter femoral heads. In this study, we examine the relationship between contact pressures developed between the anterior hip and the iliopsoas musculo-tendinous complex as a function of femoral head size and hip position.

MATERIALS and METHODS: Six fresh human hemi-pelves (5 male, average age: 60±13 years) were harvested from cadaveric donors and dissected leaving the hip capsule, psoas, iliacus, and ligamentous structures intact. The specimens were then CT-scanned, and 3D models were created to track joint angles and translations during testing. After preparation, an experienced joint surgeon implanted with a 32mm zirconia-toughened alumina ceramic head and a cementless, tapered stem in each femur, and a custom 3D-printed cup in the acetabulum. Correct restoration of the original head position was verified through 3D measurements of the intact and replaced hip. Before reduction of the head into the cup, a pressure sensor (Tekscan pressure mapping sensor 4205: 528 sensels, 27.6 sensels/cm^2, max pressure: 2068 kPa) was inserted between the separated joint capsule and the iliopsoas musculo-tendinous complex. Iliopsoas contact pressures were measured under a constant psoas load of 370N , scaled to 25% of physiologic levels to preserve the cadaveric tissue during testing. The contact pressure distribution was measured in 3 positions: (i) neutral extension/15â° external rotation (Position 1); (ii) 10â° extension/ 25â° external rotation (Position 2) and (iii) 15â° extension/ 35â° external rotation (Position 3). Joint placement was verified with a six-camera motion analysis system. All experimental measurements were repeated with a 44mm Delta ceramic head. Differences in average pressure between head sizes were tested using a standard student's t-test (p<0.001).

RESULTS: The values of average and peak pressure recorded using the pressure sensor appear in Table 1. The 44mm diameter heads showed a significant increase in average pressure compared to the 32mm heads in all tested positions (Position 1: 61% (p<0.001); Position 2: 26% (p<0.001); Position 3: 27% (p<0.001)) (Figure 2)., The largest increase was observed in external rotation in neutral flexion/extension. Smaller differences were observed in peak pressures, however, none of the differences between 32 and 44mm measurements was statistically significant (Pooled values:32mm: 213±22 kPa vs. 44mm: 242±26 kPa, p=0.0858).

CONCLUSIONS:

1. Average values of iliopsoas contact pressure are larger with 44mm vs. 32mm femoral heads independent of hip position.
2. Peak pressures are sensitive to hip position, especially with 32mm heads and

tend to decrease in increasing head diameter. be lower with 44mm vs 32 mm heads. This is probably due to the inhomogeneity of the ilio-psoas musculo-tendinous complex, leading to interactions between the head profile and the tendinous band running through the iliopsoas complex, causing a non-uniform distribution of tissue stiffness under tension.

Figures

Figure 1. Specimen during testing.

Figure 1

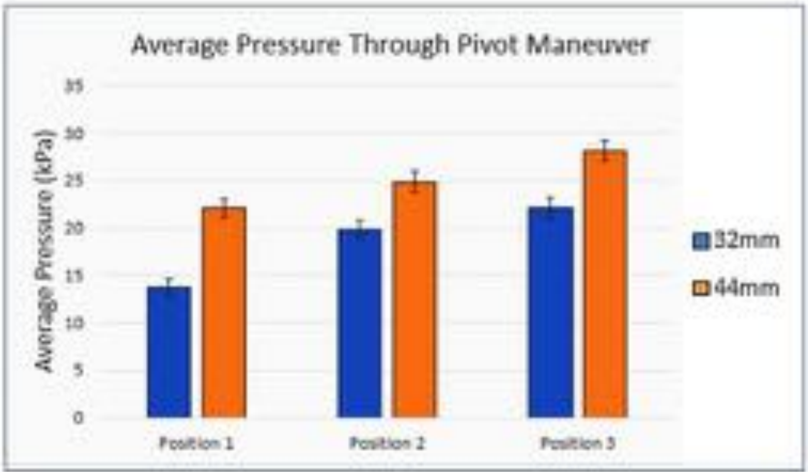

Figure 2. Average pressure in kPa on 32mm and 44mm diameter femoral heads through pivoting maneuver.

Figure 2

	Average Pressure (kPa)				Peak Pressure (kPa)			
	32 mm	44 mm	44/32	p	32 mm	44 mm	44/32	p
Position 1	13.7±0.8	22.1±1.0	1.61	<0.001	195±40	235±54	1.21	0.245
Position 2	19.8±0.9	24.9±1.1	1.26	<0.001	208±38	231±43	1.11	0.346
Position 3	22.1±1.1	28.2±1.1	1.27	<0.001	236±45	254±43	1.08	0.543
All Combined	26.1±1.3	33.0±1.3	1.27	<0.001	213±22	242±26	1.14	0.086

Table 1. Average pressures (Mean ± SE) and peak pressures for all head sizes in all tested positions.

Figure 3

#5963

Modern Press-Fit Stem Design Concept Better Allows Surgeons to Recreate Patient Biomechanics

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INTRODUCTION:

Combining novel diverse population-based software with a clinically-demonstrated implant design is redefining total hip arthroplasty. This contemporary stem design utilized a large patient database of high-resolution CT bone scans in order to determine the appropriate femoral head centers and neck lengths to assist in the recreation of natural head offset, designed to restore biomechanics. There are limited studies evaluating how radiographic software utilizing reference template bone can reconstruct patient composition in a model. The purpose of this study was to examine whether the application of a modern analytics system utilizing 3D modeling technology in the development of a primary stem was successful in restoring patient biomechanics, specifically with regards to femoral offset (FO) and leg length discrepancy (LLD).

METHODS:

Two hundred fifty six patients in a non-randomized, post-market multicenter study across 7 sites received a primary cementless fit and fill stem. Full anteroposterior pelvis and Lauenstein cross-table lateral x-rays were collected preoperatively and at 6-weeks postoperative. Radiographic parameters including contralateral and operative FO and LLD were measured. Preoperative and postoperative FO and LLD of the operative hip were compared to the normal, native hip. Clinical outcomes including the Harris Hip Score (HHS), Lower Extremity Activity Scale (LEAS), Short Form 12 (SF12), and EuroQol 5D Score (EQ-5D) were collected preoperatively, 6 weeks postoperatively, and at 1 year.

RESULTS:

The mean age is 62 years old (range 32 – 75), 136 male and 120 female, BMI 29.7. The preoperative FO and LLD of the operative hip were 43.5 mm (±9.0 mm) and 3.0 mm (±6.5 mm) compared to the native contralateral hip, respectively. The postoperative FO and LLD were 46.4 mm (±8.7 mm) and 1.6 mm (±7.6 mm) compared to the native contralateral hip, respectively. The change in FO on the operative side was 3.0 mm (±7.2 mm) ($p<0.0001$) and the change in LLD from preoperative to 6-weeks postoperative was 1.6 mm (±8.4 mm) ($p=0.0052$) (Figure 1), demonstrating the ability of this stem design to recreate normal hip biomechanics in this study. The HHS increased considerably from a preoperative score of 55.9 to 78.4 at 6 weeks and 92.7 at 1 year. Clinically significant improvements were also seen at 1 year in the LEAS (+2.3), SF12 PCS (+16.3), and EQ-5D TTO (+0.26) and the EQ-5D VAS (+15.7).

DISCUSSION and CONCLUSION:

This study demonstrated that recreation of normal anatomic leg length and offset is possible by utilizing a modern fit and fill stem that was designed by employing an advanced anthropomorphic database of CT scans. We hypothesize that when surgeons utilize this current fit and fill stem design, it will allow them to accurately recreate a patient's natural FO and leg length, assisting in the restoration of patient biomechanics.

Summary Sentence: In this study, modern design methods of a press-fit stem using 3D modeling tools recreated natural femoral offset and leg length, assisting in the restoration of patient biomechanics.

Figures

Figure 1

#5708

Implantation of Short Stem Hip Prothesis Type Aida Using a Minimally Invasive Anterolateral Approach: Intermediate Term Clinical and Radiological Results.

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Aim: The objective of this study was to evaluate the intermediate term clinical and radiological results of a new short stem hip implant.

Methods: In 20 consecutive patients suffering from osteoarthritis with 25 affected hip joints (five cases were bilateral), the clinical and radiological results of 25 hip arthroplasties performed in one hospital between October 2009 and May 2014 through a minimally invasive anterolateral approach using a cementless short stem prosthesis type Aida and a cementless cup type Ecofit with a ceramic on ceramic pairing were evaluated prospectively. The median age of patients at time of surgery was 60 years (range, 42-71 years), 15 male (4 were bilateral) and 5 female patients (one was bilateral) were included in the study. The median clinical follow up was 30 months (range, 2-88 months), and the median radiological follow up was 30 months (range, 2-88 months).

Results: Harris Hip Score improved from a median preoperative value of 53 to a median postoperative value of 96 (range, 73-100) at follow up. 22 hips (88%) showed an excellent postoperative Harris Hip Score, 2 hips (8%) a good postoperative Harris Hip Score, and one hip (4%) a fair postoperative Harris Hip Score. Only two patients complained of postoperative thigh pain. Regarding patient satisfaction, 15 patients (60%) were very satisfied, 10 patients (40%) were satisfied. None was unsatisfied.
Radiological analysis showed that 19 stems (76%) were with stable bony ingrowth, two cases (8%) showed stable fibrous ingrowth. Four cases need further follow up for proper evaluation of stem fixation.(See Figures 1,2,3)

Conclusion: The intermediate term survival of this new short stem is very promising, and achieving the goals of a standard hip arthroplasty.

Key words: short stem, hip arthroplasty, osteoarthritis.

Figures

Figure 1

Figure 2

Figure 3

#6027

Novel Hip Stem Designed for Direct Anterior THA Demonstrates Encouraging Outcomes and Low Device Related AE Rate at 90 Days

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Background and Introduction: A novel femoral stem designed for primary total hip arthroplasty (THA) via direct anterior approach (DAA) demonstrates good clinical outcomes and a low device related adverse event (AE) rate at 90-day follow-up.

Objectives: To assess early post-operative performance of the Actis Total Hip System by summarizing adverse event rates within 90 days following surgery and clinical outcomes at 90-day follow-up.

Study Design and Methods: This was an interim analysis from an ongoing multi-center prospective case series of 227 DAA THAs, all of whom are in or beyond the 90-day follow-up interval. Serious AEs, device related AEs, and procedure related AEs through 90 days post-op were summarized. The Harris Hip total score and the percent of subjects who said they would have the procedure again were summarized from a 90-day follow-up interval (71 to 132 days post-operative).

Results: There were 3 revisions of any component for any reason; only 1 revision required removal of the Actis stem. There were 2 reoperations: 1 for superficial wound breakdown and 1 for skin infection. One subject had 2 dislocations that resulted in a revision of the head and liner. Two deaths occurred, 1 for cardiac arrest and 1 secondary to infection; neither were device related. Of the 17 AEs reported 16 were coded as procedure related and 6 as device related. No unexpected AEs were reported. The average Harris Hip total score for responding subjects in the 90-day post-operative interval (n=187) was 93.6 (SD = 8.7). The percent answering 'Yes' to the question "Would you have this procedure again?" was 95.8% (N = 189) in the 90-day post-operative interval.

Conclusions: A novel hip stem designed for DAA THA demonstrated overall low device related complication rate (6/227, 2.6%), good Harris Hip outcomes, and a high percent of subjects who would have the procedure again at 90 days post-operative.

#6124

Clinical and Radiographic Outcomes of Minimally Invasive Anterolateral THA Using a Short Femoral Stem in Japanese Patients

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Introduction: The Taperloc Microplasty (ZIMMER BIOMET) is one of short femoral stems. It was launched in Japan in 2012. It is essentially a shortened version of the Taperloc stem (35mm shorter than the standard stem).

Objectives: The objective of this study is to evaluate the clinical and radiographic outcomes of total hip arthroplasty (THA) using short femoral stem (Taperloc Micropasty) in Japanese patients.

Methods: We retrospectively reviewed all 86 THA between July 2013 and December 2017 at our institute, and 46 THA (53%) were done with short femoral stems. A single orthopedic surgeon performed all THA procedures. The surgical approach was antero-lateral in the lateral position in all cases. The mean age of patients (4 men and 42 women)at the time of surgery was 68.1 years (range, 46-85). The original diseases were 41 osteoarthritis , 4 osteonecrosis and 1 rapidly destructive coxopathy.

*Results:*â€€There was no revision, infection, deep vein thrombosis, nor dislocation. One patient had femoral fracture during the surgery, we had to switch the stem to the standard one in this case. The average surgery time was 114 minutes (range, 80-168 minutes); the average blood loss during surgery was 298 g (range, 90-720 g). The cup we used was Regenerex M2a Taper (ZIMMER BIOMET). Median cup size was 50 mm (range, 48-60 mm); median stem size was 8 (range, 4-13). The bearing surfaces were all ceramic on highly cross-linked polyethylene. Radiological findings showed stem subsidence (within 5mm) in 3 patients; two patients had severe osteoporosis, while the other had leg length discrepancy.

Conclusions: THA using a short femoral stem has satisfactory clinical and radiological results in Japanese patients.

#6001

Comparison of Patient Reported Outcomes in Neck-Preserving Short-Stem Implant vs. Conventional Neck-Sacrificing Implant

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Background

Recent studies indicate the benefits of total hip arthroplasty (THA) by using femoral neck-preserving short-stem implants (March et al 1999). These benefits rely on the preservation of native hip structure and improved physiological loading. However, further investigation is needed to compare the outcome of these implants versus the conventional neck-sacrificing stems particularly assessed by patient-reported outcomes (PROs). In this study, we have investigated the differences in PROs between a neck-sacrificing stem design and neck-preserving short stem design (MiniHip, Corin Inc.). We hypothesized higher PROs outcome in patients who received treatment by using neck-preserving implants.

Methods

In this study, we retrospectively analyzed the pre and post-operative PROs of patients receiving THA treatment by using neck-sacrificing implant (n=90, age 57±7.9 years) and a matched (BMI, age) cohort group of neck-preserving patients (n=105, age 55.16±9.88 years). Hip disability and Osteoarthritis Outcome Scores (HOOS) were using with the follow-up of similar follow up of 412.76 ± 206.98 days (neck sacrificing implant) and 454.63 ± 226.99 days (Neck-Preserving). Multivariate analysis of variance and Mann-Whitney tests were conducted for statistical analyses. Holm-Bonferroni adjusted for multiple comparisons was used with initial significance level of 0.05.

Results

Both implants resulted in significant improvement of HOOS Subscores ($p<0.001$). There was a significant effect of time-surgery interaction ($p=0.02$). Follow-up HOOS subscores analysis indicated that patients who were treated with neck-preserving stems reported significantly higher Symptoms ($p<0.001$), Pain ($p<0.001$), ADL ($p=0.011$), Sports and Recreation ($p=0.011$), & QOL ($p=0.007$) subscores.

Conclusion

This study aimed to investigate the short term to medium term outcome of neck-preserving implants. The superior outcome of neck-preserving femoral stems could be a result of more natural physiological loading in femoral cavity and higher retention of bone tissue in femoral neck area. However, further studies are needed to investigate the longer-term outcome of these implants.

Reference:

March LM, Cross MJ, Lapsley H, Brnabic AJM, Tribe KL, Bachmeier CJM, et al. Outcomes after hip or knee replacement surgery for osteoarthritis. A prospective cohort study comparing patients' quality of life before and after surgery with age-related population norms. Med J Aust 1999;171:235–8.

Figure 1. Finite element model of the femoral loading distribution a) intact femur b) femur implanted with a neck-preserving short-stem implant c) femur implanted with a conventional neck-sacrificing implant. Permission from Corin Ltd.

Figure 2. Comparison of postoperative X-rays of THA with a conventional neck-sacrificing implant (a) and a neck-preserving short-stem implant (b). The cutting angle is different between both implants (black line), with the neck-preserving short-stem implant preserving more native femoral bone.

Table 1. Pre-operative and Post-operative HOOS subscale averages and standard deviations (SD) in patients with neck-sacrificing and MiniHip implants.

			Symptom	Pain	ADL	Sport	QOL
Neck-Preserving	Pre	X	44.5	43.8	49.2	26.6	21.8
		SD	16.7	13.7	16.8	19.3	15.9
	Post	X	92.7	94.0	94.3	87.1	82.2
		SD	10.0	11.3	9.0	16.3	19.3
			Symptom	Pain	ADL	Sport	QOL
Neck-Sacrificing	Pre	X	40.1	42.0	44.8	23.8	22.3
		SD	18.7	16.6	18.8	19.3	15.6
	Post	X	84.9	88.2	89.6	79.1	74.4
		SD	15.2	16.2	15.4	22.2	21.7

Figures

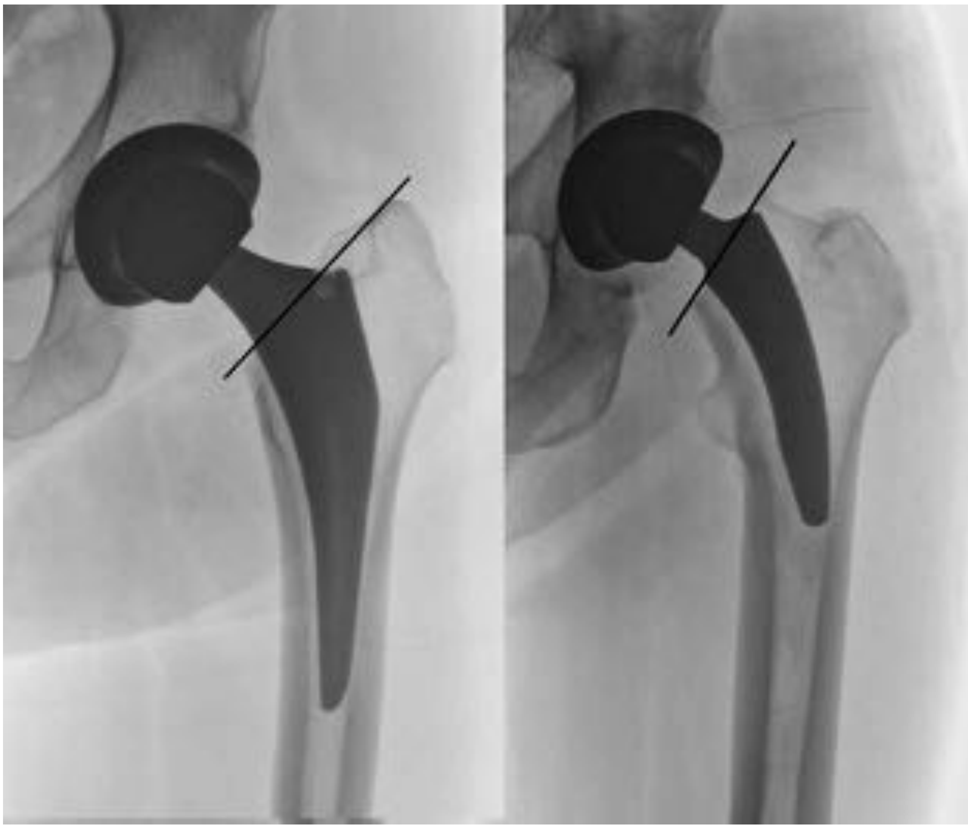

Figure 1

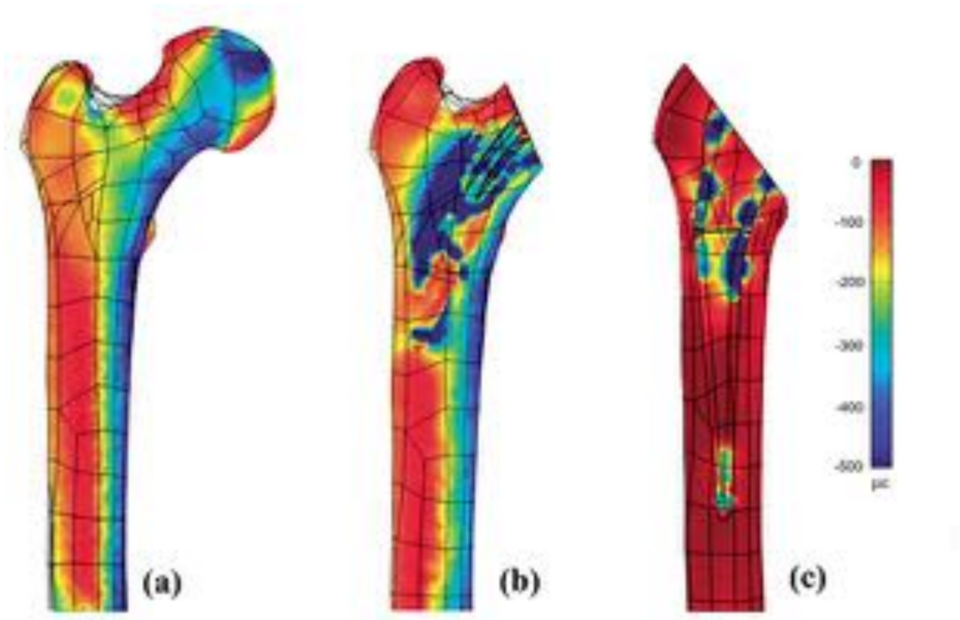

Figure 2

#5761

MiniHip Femoral Stem: A Multi-Centre, Prospective, Observational Study

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INTRODUCTION: Historically, the clinical performance of novel implants was usually reported by designer surgeons who were the first to acquire clinical data. Regional and national registries now provide rapid access to survival data on new implants and drive ODEP ratings. To assess implant performance, clinical and radiological data is required in addition to implant survival. Prospective, multi-surgeon, multi-centre assessments have been advocated as the most meaningful. We report the preliminary results of such a study for the MiniHip™femoral component and Trinity™ acetabular component (Corin Ltd, UK).

METHODS: As part of a non-designer, multi-surgeon, multi-centre prospective surveillance study to assess the MiniHip™stem and Trinity™ cup , 535 operations on 490 patients were undertaken. At surgery, the average age and BMI of the study group was 58.2 years (range 21 to 76 years) and 27.9 (range 16.3 to 43.4) respectively. Clinical (Harris Hip Score, HHS) and radiological review have been obtained at 6 months, 3 and 5 years. Postal Oxford Hip Score (OHS) and EuroQol-5D (EQ5D) score have been obtained at 6 months and annually thereafter. To date, 23 study subjects have withdrawn or lost contact, 11 have died, and 9 have undergone revision surgery. By the end of March 2018, 6 month, 1, 2, 3, 4, and 5 year data had been obtained for 511, 445, 427, 376, 296 and 198 subjects respectively.

RESULTS: Implant revision rate is 1.68% (9/535), with revision for any reason as an endpoint; four of the nine involved the revision of the femoral component. At the 5-year time point, mean OHS had improved from 21.3 to 42.5 ($p<0.01$), EQ5D from 0.42 to 0.82 ($p<0.01$), and HHS from 51.6 to 92.5 ($p<0.01$). Radiological analysis is ongoing, and thus far has revealed more variation in stem alignment than is usually observed for more conventional length femoral components. This may indicate that optimal alignment of calcar loading short stems is different to that of longer, medullary canal aligned implants, consistent with the neck-stabilised design of the MiniHip™ stem. No other significant radiological findings were noted. During surgery, 31 calcar fractures were sustained, of which 20 were treated with cerclage wiring, 1 with femoral grafting and the remainder required no treatment. None of the hips with calcar fractures have been revised to date.

DISCUSSION: The clinical and radiological performance of the MiniHip™ femoral stem is consistent with established femoral implants. Longer surveillance will determine whether this performance is maintained. Patients in this study will be continued to be followed-up and reviewed at the 7 and 10-year time points.

CONCLUSION: The MiniHip™ stem is safe and efficacious at mid-term follow-up.

#5502

AMIStem Can Mostly Preserve the Short External Rotators. -Preoperative Planning for the Stem Insertion in DAA-THA-

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Background: In recent years, MIS-THA has been widely used for the purpose of early social reintegration in Japan. Our hospital also introduced a direct anterior approach (DAA), which is a muscle preservation type MIS-THA, and gained good results. How to lift up the femur in DAA is important for inserting the stem and it is necessary to partly release the short external rotators depending on the extent of lifting. Depending on the shape of the stem, the group of short turns may be damaged during insertion.

Objects: The aim of this study is to simulate stem insertion using preoperative 3DCT template.

Sturdy Design ï¼†ã€€Methods: The patients who had undergone DAA-THA was simulated stem insertion using preoperative 3DCT template(Zed Hip, manufactured by LEXI). the 20 participants were mean age at 66.4 years; and 3 male and 17 female. On the Zed Hip, stem insertion simulation of five kinds of stems (J-Taper, Accolade, TaperLoc Microplasty, HYDRA, AMIStem) was performed(Fig.1). We measured the angle at which the elevation at the greater trochanter retractor is required when inserting the stem (The angle formed by the femoral bone axis and the tangent line connecting the outer part of the stem and the greater trochanter top part, the femoral elevation angle) .We also measured the distance between the point where the stem outer part contacts the bone cortex of the greater trochanter inner edge at the time of insertion and the greater trochanter top part (the distance between the stem-greater trochanter top parts). The difference in each stem was compared and examined.

Results:The femoral elevation angle (average) was 122.0 ± 4.0 ° for Accelerade 2, 115.9 ± 4.4 ° for J-Taper , 109.5 ± 4.9 ° for Microplasty , 135.3 ± 5.0 ° for HYDRA, 112.9 ± 5.9 ° for AMIStem(Fig.2). Significant difference was recognized between J-taper and AMIStem, Microplasty and AMIStem for each model. The optimum size stem tended to require femoral elevation as the stem length was longer. The distance between the stem-greater trochanter top parts (average) was 11.3 ± 3.9 mm for Accolade 2, 13.9 ± 4.7 mm for J-taper, 15.1 ± 5.5 mm for Microplasty, 3.7 ± 5.6 mm for HYDRA and 21.3 ± 3.7 mm for AMIStem(Fig.3). A significant difference was observed between the Taper wedge design (Accorade 2, J-Tper, Microplasty), the Corail type stem (HYDRA), and AMIStem. The distance between the stem-greater trochanter top parts became high if the stem length was short and further the stem outer flare Was dominantly high in AMIStem that was most reduced.

Conclusions: We select implants by performing simulation before surgery. Before surgery, it is important to understand the medullary canal shape, anteversion of the femoral neck etc, and to select an appropriate implant for avoiding intraoperative complications. The preoperative simulation was thought to be useful because it could predict the possibility of dissection of the short external rotators due to elevation of the femur and the possibility of damage of the short external rotators when inserting the stem.

Figures

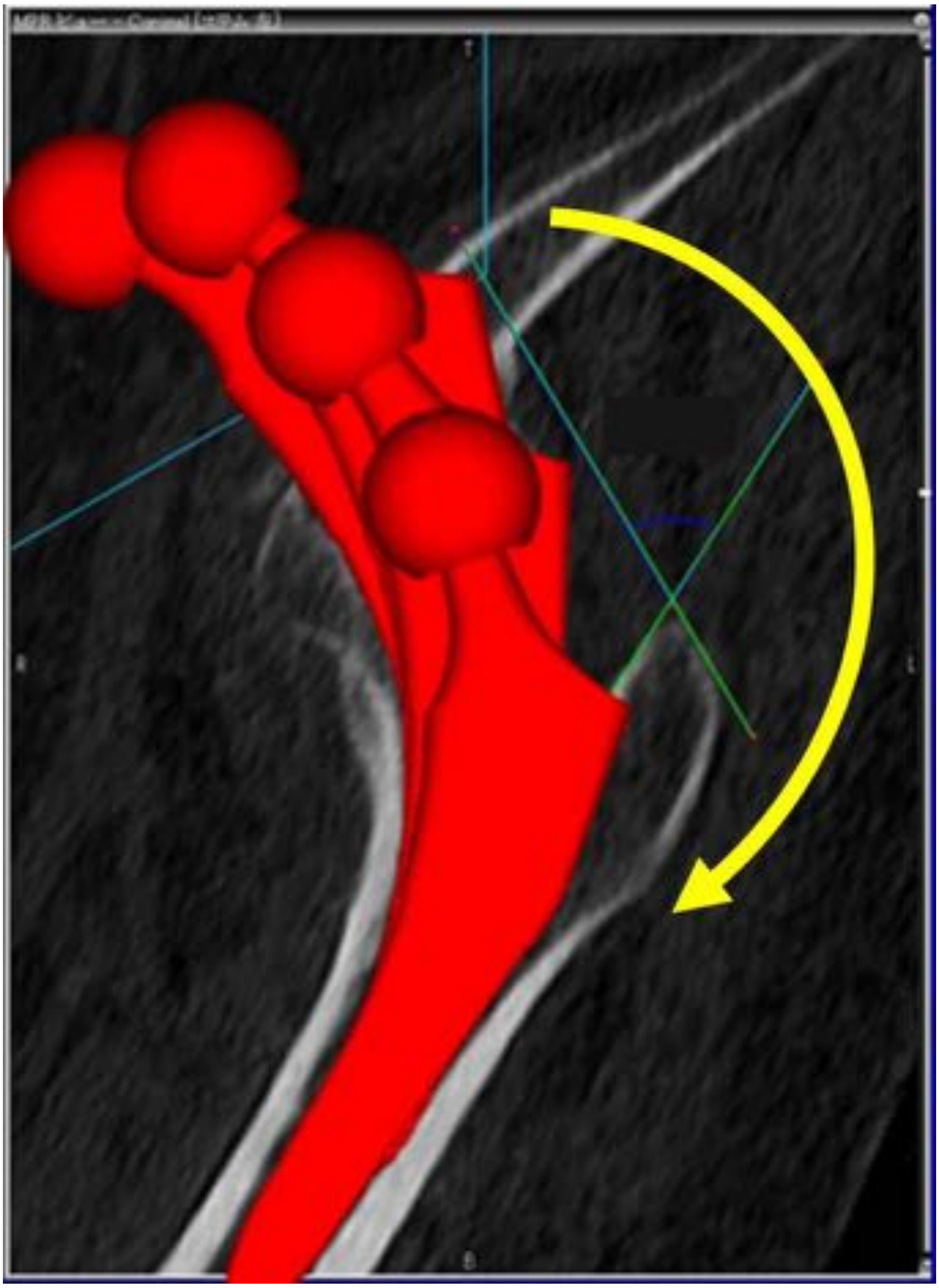

Figure 1

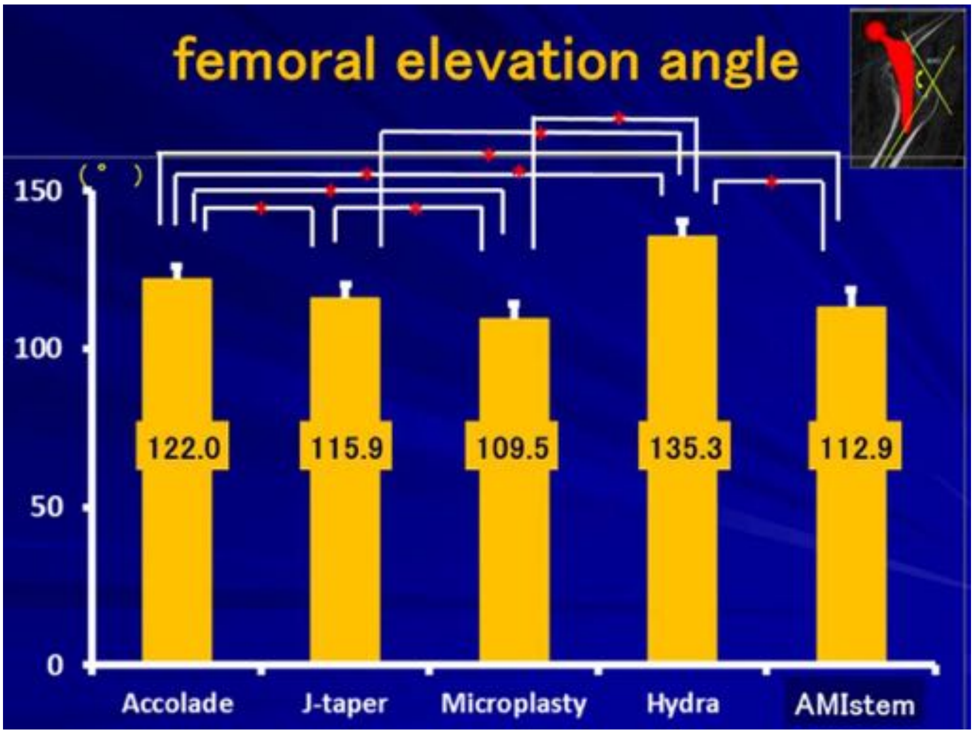

Figure 2

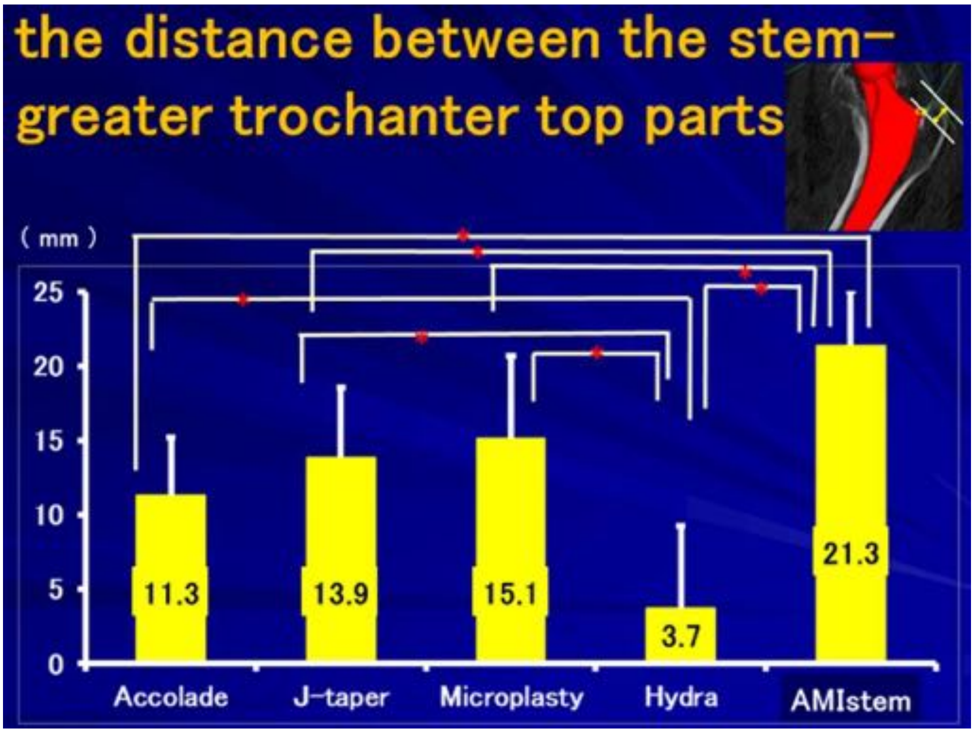

Figure 3

#5681

Results of Short Stem Hip Prostheses as a Conservative Hip Arthroplasty

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The objective of this study was to evaluate the short term clinical and radiological results of a new short stem hip implant. In 29 consecutive patients suffering from osteoarthritis with 33 affected hip joints, the clinical and radiological results of 33 cementless hip arthroplasties using a cementless implanted short stem prosthesis type Aida and a cementless cup type Ecofit were evaluated prospectively between October 2009 and June 2015 in two hospitals. The median age of patients at time of surgery was 55 years (range, 30-71 years), 23 male and 10 female patients were included in the study. The median clinical follow up was 24 months (range, 1.5-51 months), and the median radiological follow up was 12 months (range, 1-51 months). Two patients were lost to follow up and two patients had only one immediate postoperative x- ray. The Harris Hip Score improved from a median preoperative value of 53 to a median postoperative value of 93 at follow up. Radiological analysis showed that 19 stems (58%) showed stable bony ingrowth, five cases (15%) showed stable fibrous ingrowth. Four cases need further follow up for proper evaluation of stem fixation. The short term survival of this new short stem is very promising, and achieving the goals of standard hip arthroplasty.

Key words: short stem, hip arthroplasty, osteoarthritis.

Figures

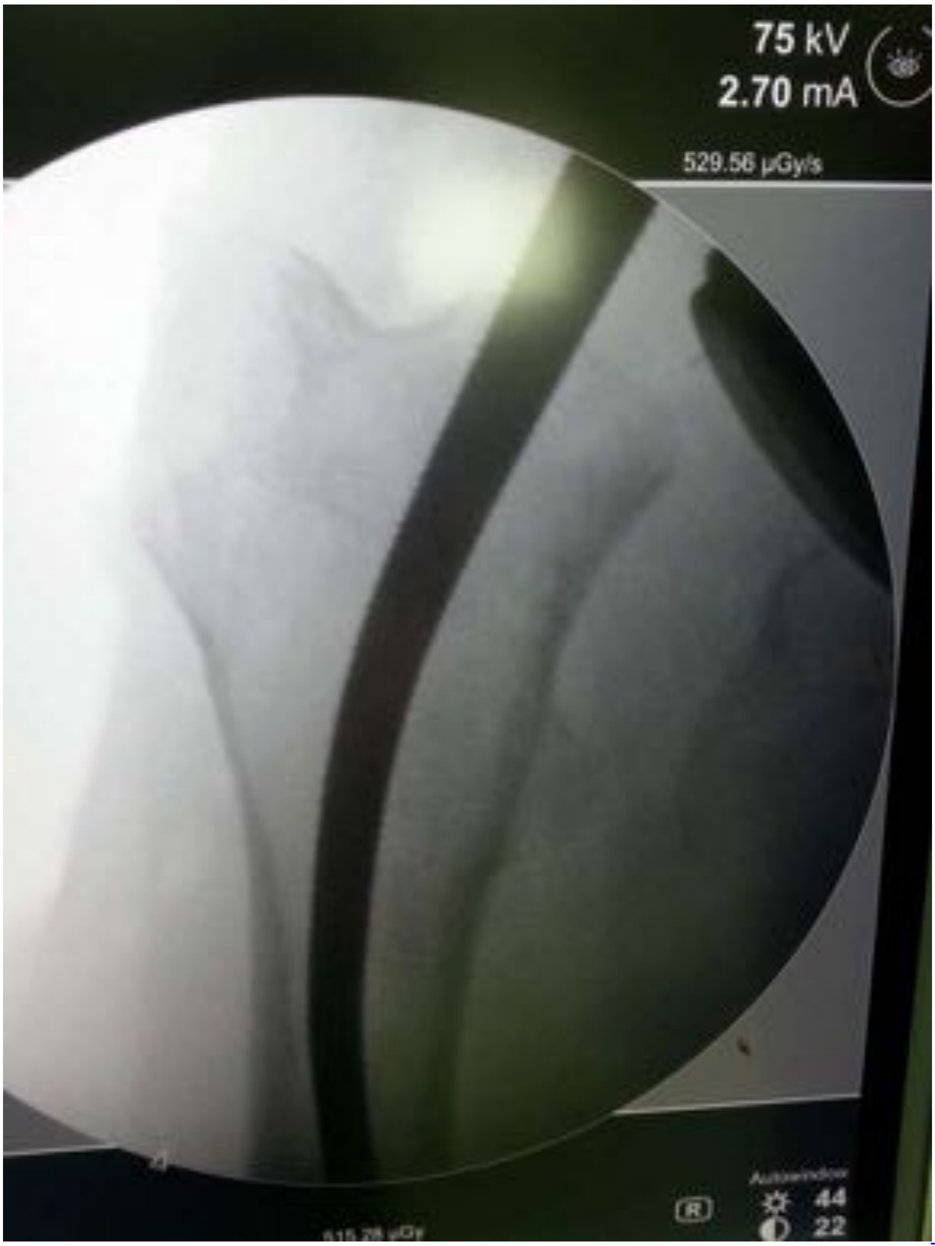

Figure 1

Figure 2

Figure 3

#5693

Early-Mid Term Results of a Cementless Short Hip Stem Prothesis

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The use of a cementless short femoral stem (SFS) may have a number of advantages: bone stock and soft tissue preservation, in the greater and sub-trochanteric regions, at the time of implantation for future revisions; decreased stress shielding. Because of these advantages, we use SFS. In this study, we evaluated the results of THP with SFS.

Materials and methot

This is a retrospective study of patients treated with SHS. Surgeries were performed between 2013 and 2016. All patients over the age of 18 were included in the study. All THP were performed using a posterior approach. Patients were mobilized on the first postoperative day with full weight-bearing but limitation of flexion to 80°.

Radiological and clinical examinations were performed preoperatively and at each follow-up visit postoperatively. All adverse events and complications during the follow-up period were recorded and analyzed.

The Harris Hip Score (HHS), visual analogue scale (VAS) were all recorded. WE evaluated of the implant position: femoral stem; neutral (130- 40°), varus (<130°) or valgus (>140°), acetabulum; anteversion and incliation angle eveluated on posterior radiographs of the pelvis on postoperative 1st day and at last follow-up. Radiolucent lines on AP radiographs of the pelvis, osteolysis and heterotopic ossifications (HO) were noted.

Differences were detected by measuring the leg lengths.

Results

Figure 1 contains follow-up data.

All patients received cementless cup arthroplasty treatments with ceramic-PE pairings (Figure 2, 3). 2 patients were revised after repetitive dislocation, 2 patients were due to aseptic loosening and 1 patient was protruded after 3 weeks of operation. 1 patient was infected and revision was performed. Three patients had superficial wound infection and were treated conservatively. Intraoperative acetabulum fracture was seen in 1 patient, followed conservatively. Two patients had Type 2 HO.

At the last follow-up examination, 83% of patients were very satisfied with the results of the treatment, 16% were satisfied and 1% were dissatisfied. For one of the dissatisfied patients, had recurrent operations due to infection.

Discussion

The clinical results revealed a high average HHS of 96 points. The subjective patient satisfaction level was also high, with 83% of patients reporting that they were very satisfied and 16% as being satisfied. Studies with the SFS type over a shortterm period revealed a HHS of 95 points and a total of 96% satisfied patients.

In our study, 6 hips were revised. We think, infection, protrude acetabuli and repetitive dislocation, are not related to the use of SFS. Two patients underwent revision due to femoral aseptic loosening. We thought it might be interesting to use SFS. Similar complications have been reported in the literature.

We revised the SFS with a standard femoral stem. This is an advantage of SFS.

There are some limitations to this study. Firstly, absence of a standard femoral stems group compared to the SFS. Secondly, short follow-up of patients.

Conclusion

We think that SFS results are good in the early-mid term as a result of our work and are frequently applied because of the advantages mentioned in the article.

Figures

Patient	101
Hips	113 (12 bilateral)
Females	68
Males	45
Mean age	58,5 (18-80)
Mean follow-up	32,3 months (25,3-40,2)
Primary coxarthrosis	59
Dysplasia coxarthrosis	31
Femoral head necrosis	14
Others	9
HHS	
Preoperative	49 (22-70)
Postoperative (at last foolow-up)	96 (66-100)
VAS	
Preoperative	6.9 (1.6-9.4)
Postoperative (at last foolow-up)	0.23 (0-6.6)
Femoral stem (at last foolow-up)	2 (varus)
Acetabulum (at last foolow-up)	
Incliation angle	47 (33-53)
Anteversion angle	14 (10-19)
Leg length difference	
10 patient	0,9cm (0,3-2) long
6 patient	1.2cm (0.5-2.1) short

Figure 1

Figure 2

Figure 3

#5874

Cementless Total Hip Replacement With a Lateral Flare Stem: An Average of 15 Years Follow Up of a Previously Reported Case Series

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Introduction: From clinical experience over the past 60 years with total hip replacement (THR), it is evident that most femoral implants for total hip replacement do not restore the normal physiological loading of the femur, because these implants are focus on only the medial loading, instead of the medial and lateral loading of the femur. Moreover, to achieve an initial rigid stability of the cementless stem, cementless implants employ a "press fit" technique. However, the press fit technique has also been associated with an increased risk of intraoperative periprosthetic fracture of the femur. To demonstrate the physiological and mechanical forces on the femur in THR, the cementless "lateral flare", with a "rest fit" fixation technique, femoral stem has been developed, established, and clinically validated at our institution. Previously we had reported the mid-term outcomes, and therefore, the long-term outcomes of this femoral stem was evaluated in this study.

Patients and methods: A total of 62 hips in 58 consecutive patients underwent THR with a cementless lateral flare stem at our institution from January 1998 to December 2000 were investigated by physical examinations, radiographic evaluations, and telephone interviews.

Results: There were 49 hips in 45 patients (79.0%) available for long-term follow-up. Of the 49 hips, the mean age at the time of operation was 56.9 ± 12.2 years (31-81 years) and the mean duration of follow-up period was 15.8 ± 1.5 years (10.1-17.9 years). Two patients had received acetabular cup revisions 13 years after their index surgeries due to polyethylene failure of the acetabular component. One patient, a 65-year-old female, displayed second-degree stress shielding 15 years after the initial THR. However, there were no cases of critical stress shielding which required revision surgery of any femoral components. Consequently, no femoral components have been revised at the time of this report.

Discussion and Conclusions: Besides the lateral expansion, this femoral stem has a trapezoidal shape of the cross section in the proximal one-third so as to stabilize the cementless implant against rotation forces encountered inside the femoral canal during stair climbing. Moreover, it has a flat posterior surface with a fixed anteversion in the neck. This allows a maximal load transfer between the component and the posterior aspect of the femur along the calcar femorale during hip flexion activities. Because of these features, a smaller size of this stem compared to the conventional stem is selected for the implantation. It is called the rest fit, instead of the press fit, which has a possibility for the periprosthetic fracture in THR. For these reasons, the lateral flare stem is a promising prosthesis with a carefully considered design, which provides not only initial stability but long-term stability and bone preservation throughout a long follow-up period.

#6103

Investigation of the Correlation Between Preoperative Bone Density and Clinical Outcomes at 2 Years Follow-Up Following Cementless Total Hip Arthroplasty

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Introduction : The success of cementless total hip arthroplasty (THA) depends on the primary stability of the components. One of the biomechanical factors that comes into play is the mechanical quality of the bone. To our knowledge, there are no reported studies in the literature analyzing the impact of the preoperative bone mineral density on the outcomes of cementless THA. The goal of the study was to analyze the clinical results at 2 year follow-up according to the preoperative cancellous bone mineral density (BD). Our hypothesis was that the clinical outcomes were correlated to the BD.

Material and methods

From January to June 2013, a prospective study included patients who underwent a cementless THA using a proximally shortly fixed anatomic stem. A 3D preoperative CTscan-based planning was performed according to the routine protocol using the Hip-Plan software in order to determine the hip reconstruction goals as well as the implants size and position. The Hounsfield bone density (BD) of the metaphyseal cancellous bone was computed in a volume (of 1 mm thick and of 1cm² surface) at the level of the calcar 10 mm above the top of the lesser trochanter and laterally to the medial cortical (Figure 1). Intra-and inter-observer repeatability measurements were performed. Patients were clinically assessed at 2 years follow-up using self-administered auto-questionnaires corresponding to the Harris and the Oxford scores. A Multivariate statistical analysis assessed correlations between clinical scores, age, gender, body mass index, and BD.

Results

50 patients were included consisting of 29 men and 21 women, with an average age of 62 ± 12 years and an average BMI of 25.8. The average preoperative BD was 69.4 ± 54 HU. At 2 years follow-up, the hip function scores were significantly correlated with the preoperative BD (0.42, $p = 0.002$) and the age (0.39, $p = 0.005$). However, there was no significant correlation between BD and BMI.

Discussion Bone density appears to be an important parameter to consider when planning THA. This highlights also the importance of preoperative image calibration

Conclusion

The functional outcomes after cementless THA are correlated with preoperative cancellous bone density. Bone density needs to be integrated into THA 3D planning.

Figures

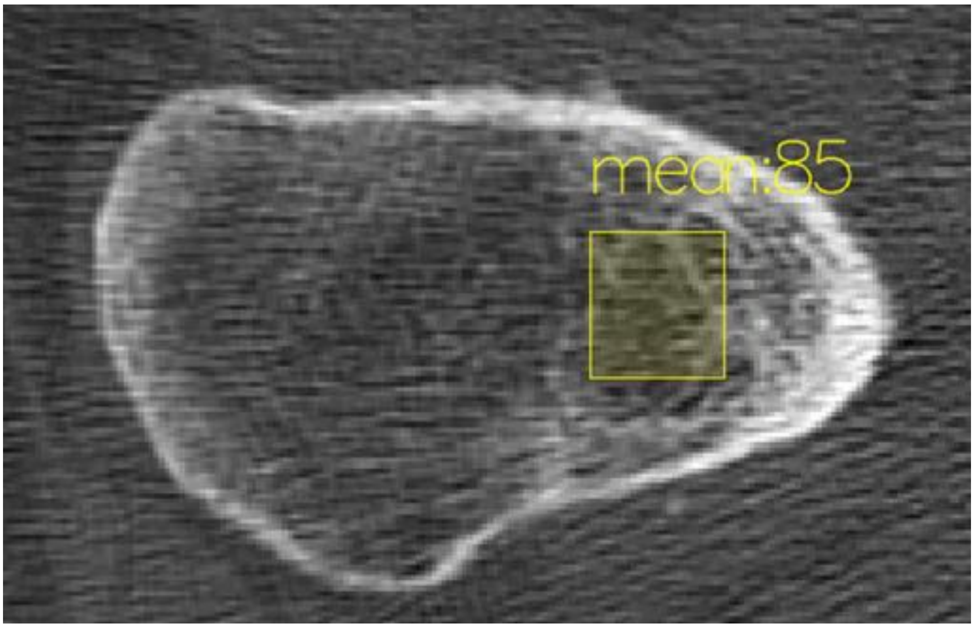

Figure 1

#6122

Clinical Results of Total Hip Arthroplasty for the Rheumatoid Arthritis Patients.

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[Objectives] We report about the clinical results of total hip arthroplasty (THA) for rheumatoid arthritis (RA) patients in10 years from December in 1997 to November in 2007.

[Materials & Methods] Total operations were 300 cases. Primary operations (P group) were 263 cases, and 37 cases were revision operations (R group). 27 cases (9.0%) in 300 cases were the RA patients, 22(8.4%) cases were in the P group, and 5 cases (13.5%) were in the R group. 17 patients were in Stage III, and 10 patients were in Stage IV. 15 patients were in Class II and 12 patients were in Class III. The average time of disease duration was 9.8 months. The average age was 63.2 years old at the time of surgery. Average of preoperative Japanese Orthopaedic Association (JOA) score was 49.7 points. We used mainly PSL cup / SecurFit series (Stryker Corporation) in the P group. In the R group we replaced 5 implants of 4 cups and 1 stem.

[Results] The average point of JOA score was 80.2 points after surgery. In the P group no one was performed revision operation. There was no patient had infection, dislocation, DVT/PE. In the R group we had to operate three times in the same patient for cup revision. In the first revised operation, we used KT-plate with impaction bone grafting (IBG). After 4 years, KT-plate was broken, so the second revision performed with IBG and mesh plate. After 2 years, we found central migration of socket. The third operation was performed with BSRC. Finally we could successfully reconstruct acetabulum.

[Conclusion] In THA operation for RA patients, we have some technical problems; for example, central migration, poor bone quality, and compromised conditions, multiple joint deformations and dysfunctions. It is important that we have preoperative preparation in cases of advanced deformation and bone defect. Including the control of RA, careful follow-up after surgery is desirable as RA patients.

Figures


Figure.1
76Y.O. Male
Pre-ope. 1
Revision 1
Pre-ope. 2
Revision 2
Pre-ope.3
Revision 3

Figure 1

#5798

Post Marketing Trial Results of Total Hip Replacement Using Mp_1

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The need for a more durable, metal free, non-osteolytic particle generating material in Total Hip Replacement (THR) is urgently required to reduce revision surgeries. Current used materials; Ceramic, metal and UHMWPE remain discrepant for long-term use. Polyimide (MP-1™) is a high performance biopolymer, originating from aerospace industry. MP-1™ is heat resistant, highly cross-linked and exhibits a self-lubrication property required for bearings and articulating joints. Being resistant to fatigue, creep and chemicals and sterilisable by autoclave or irradiation, MP-1™ is ideal for medical devices.

Finalizing pre-clinical testing, two patients were implanted 12 years ago after informed consent. A PM (Post Mortem) retrieval at 6.5 years, showed no measureable wear, a bland synovium, and no osteoclastic or bone marrow reaction. The 12 Y patients' hip, a revision from Polyethylene wear to MP-1™, has an unchanged radiograph and is fully active (fig. 1).

The Ethical Committee approved 100 patients in a single surgeon (PJB) post-marketing trial running Delta ceramic femoral ball against MP-1™ liner. Age range is from 81 to 43 years. The younger patients now being offered MP-1™, in view of the retrieval data. The MP-1™ acetabular liner is 4mm thick, as currently used in a LIMA PF shell, which replaces Polyethylene, Ceramic or dual mobility options.

Out of the 74 enrolled patients, 44 patients have the implant for more than 5 years. The only “Complications” in a few patients was an initial squeak which spontaneously disappears by 10 days and never returns. This is likely due to reduced clearance between head and liner and likely easily correctable. There have been no dislocations or restrictions on activity level. Oxford and Harris Hip scores along with radiology, blood and clinical examination are collected during follow-up.

MP-1™ liner on Delta ceramic head in THA, or in the future with MP-1 head, looks very promising with advantages of ease of sterilization, insignificant wear, no tissue reactivity and ability to have thin section and larger femoral heads if desired for larger range of motion.

MP-1™ biomaterial is used for other medical devices as well such as dental implants and trauma nails,Plates and screws.

Figures

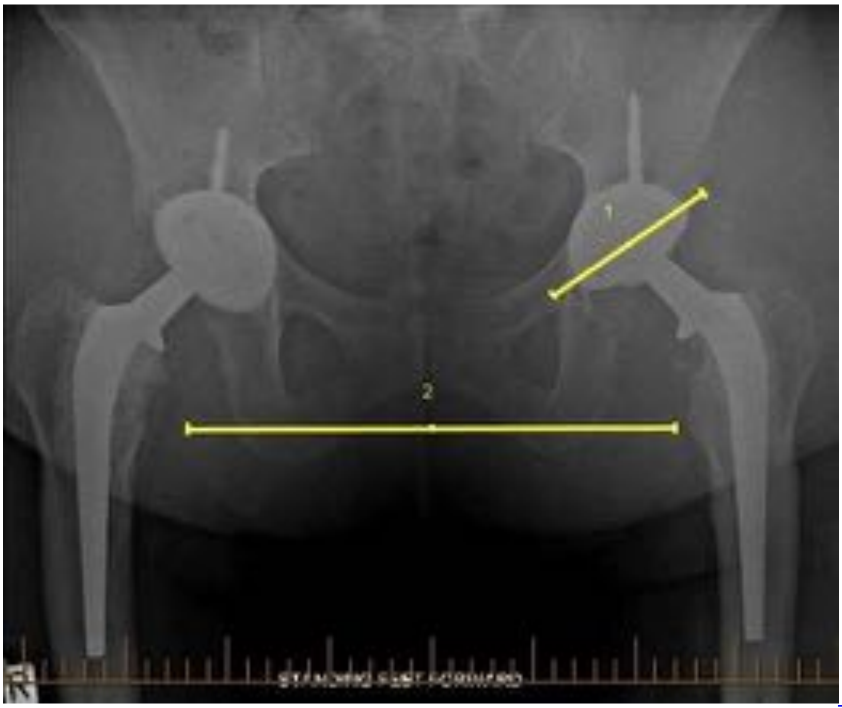

Figure 1

#5676

Investigation of the Factor That Advanced Opposite Initial Hip Arthrosis to End-Stage Hip Arthrosis After One-Sided Total Hip Arthroplasty (THA) in Patients With Bilateral Sublux Hip Arthropathy

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ã€Introductionã€' In routine practice, the course of the contralateral initial hip arthropathy after unilateral THA in patients with bilateral sublux hip arthropathy, some cases progresses to terminal hip arthrosis with time to surgery or other cases whose the joint space is kept and the follow-up observation continues conservatively with a mild pain. In this study, we examined the differences between the case of progression from initial arthropathy to the terminal arthropathy which continuous to THA and the case of continuing preservative treatment. ã€METHODSã€' From October 2003 to May 2012, 58 patients with initial hip arthritis on the other side during the initial THA with a diagnosis of bilateral sublux hip arthropathy were performed at our hospital were examined retrospectively by dividing into 36 preservation treatment group and 22 THA treatment group. The examination items were age, height, weight, BMI, body weight gain at the time of initial surgery, CE angle, Sharp angle, AHI as X-ray finding. Furthermore, cases with CE angle less than 15 degrees were also examined in similar items between the two groups. ã€RESULTSã€'All examination items of age, height, weight, BMI, body weight gain at the time of initial surgery were not significant. In the X-ray findings, the sharp angle of the preservation treatment group was 47.88 degrees, and the THA treatment group was 49.30 degrees no significantly, but the CE angle of the preservation treatment group was 15.0 degrees , the THA treatment group was 9.9 degrees (p = 0.004), AHI of the preservation treatment group was 67.7%, the THA treatment group was 60.5% (p = 0.0008) significantly higher degree of acetabular dysplasia. As a result of similar examination limited to cases with a CE angle of 15 degrees or less, a significant difference was found between the preservation treatment group with AHI only (60.6%) and THA treatment group (52.1%) (p = 0.02). ã€Discussion and Conclusionã€' As a factor that advanced from initial hip arthrosis to end hip arthrosis from this study, it is related not to the physical factors such as age, height, weight gain, but to the extent of dysplasia caused by X – ray. In the present study, only the significant differences between the 2 groups were examined for each evaluation item in the backwards. Further examination items such as bone mineral density, occupation, sports history, lumbar scoliosis, pelvic backward inclination, leg length difference, etc. were needed to add and to clarify true participation factors by using multivariate analysis taking account of the condition of the THA side.ã€Summaryã€'It is revealed that the progressive factor of initial arthropathy to the terminal arthropathy which continuous to THA are CE angle and AHI.

#5872

Minimum 12-Year Follow-Up and Revision Rate Following Metal on Metal (MoM) Hip Arthroplasty.

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Background/ Purpose:

Recent literature from 2008 suggested that revision rates following MoM Hip Arthroplasty could be as high as 1 in 5 (20%) by 10 to 15 years. The main indication for revision is the adverse reaction to metal debris leading to local tissue destruction and failure of implants. The aim of this study is to determine our revision rate post MoM hip arthroplasty and determine if a correlation exists with raised metal ions.

Methods:

This is a retrospective cohort study of all patients who had MoM hip arthroplasty at our unit. 135 consecutive patients were included with a minimum follow up of 12 years since 2006. The mean age was 51 (30-82) years. Lab results were reviewed for metal ion (Chromium and Cobalt) levels and x-rays where obtained as routine follow up post procedure.

Results:

Revision rate was 6.6% at 12 years mark. There was no statistically significant correlation between metal ion levels and revision surgery. The main indication for revision surgery was infection (2.9%).

Conclusion: Revision rate following MoM hip arthroplasty is variable and is attributed to multiple factors. No correlation existed between revision surgery and raised metal ion levels.

Keywords:

Metal on Metal, Hip Arthroplasty, Metal Ions

#5871

Long Term Results of Metal on Metal Hip Arthroplasty in Younger Patients (<55 Yrs)

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Objectives:

Metal on Metal (MoM) hip arthroplasty saw a new era of popularity with the development of its second generation bearing surfaces, in the first decade of this century. However, by the end of last decade, concerns had been raised due to metal debris related complications. We aimed to determine the survival of MoM stemmed hip replacement in the younger population. We also studied the rate of revision related to adverse reaction to metal debris (ARMD) along with reviewing the clinical and radiological progress of MoM hip arthroplasty in younger age (<55yrs) group.

Methods:

This is a retrospective cohort study of patients 55 yrs old or younger, who had metal on metal (MoM) hip arthroplasty for osteoarthritis. We had 109 procedures performed on 90 patients with a mean follow up of 10 years. All patients were reviewed as per MHRA guidelines in planned follow-up clinics. Data analyses were performed using SPSS.

Results:

Survival of implant in our younger cohort was 88.1% at a mean age if 10 years, with revision for any cause as an endpoint. Mean Oxford hip score was 43. Altogether, there were 12 revisions, 7 of these were for metallosis and associated symptoms. Average time to revision was 7 years. Other analysis revealed mean acetabular cup inclination angle to be 49 degrees, but no significant correlation was found between this angle and serum metal ion levels. Serum Chromium and Cobalt levels were significantly higher in revision group.

Conclusion:

Metal on metal hip arthroplasty prime popularity time has gone. In younger population, although revision rates are higher, the surviving implants give a very good outcome in terms of patient satisfaction. Most of the patients report a desired outcome of ‘forgotten hip’.

Keywords:

Metal on Metal, Hip Arthroplasty, Metal Ions, Younger patients, Oxford hip score

Passive Ligament Tension in Natural Knees -20 25 N on Each Side Are Enough to Achieve Stability

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Introduction

The knowledge of the right amount of tension of the collateral ligaments in native knees is one of the hot topics to restore the normal kinematics in TKA. To guarantee stability in TKA there should be enough tension necessary but no overtensioning. In this study we could confirm that the tension of the ligaments is not more than 20-25N on each side (in total 40-50N) to achieve stability in the knee joint.

Methods and materials:

During an experimental activity we examined 5 cadaveric knee specimenwith intact ligaments. With the knee in full extension, a constant force was applied on the femoral bone and the displacement was measured up a plateau was reached.. This test was conducted for a knee joints with intact cruciates, then we sacrificed the anterior cruciate and in a third step the posterior cruciate even to find out if there is any change in extending the joint comparing distance and tension.

Results:

In all cases the tension was with intact ACL and after sacrificing it not more than 20 N (18-22N) in average, after sacrificing the PCL the tension for maximum laxity was in average 24 N (22-26N).

Summary:

Most devices for ligament tension work with more than 80 N to balance the knee. Especially in cases with weak ligaments or asymmetric stability can occur the problem of over- or under-tensioning to balance the knee.

In our study we could show, that less tension of the ligaments are enough to stabilize the knee.

Conclusion:

The most important point in restoring the normal kinematics in TA is preserving the soft tissue envelope. Of course there is still the need to proceed the correct cuts to secure survivorship of TKA, but there are still 20% dissatisfied patients. We think that there is a strict correlation to the soft tissue situation, even in the tension of ligaments, capsule and muscles. Proper adaption to the normal tension situation to avoid overtensioning will improve results and show the need of measurement devices to reach this aim.

#6202

Effect of an Internal Unloading Implant on Tibiofemoral Joint Stress: Simulation of Cartilage Defects

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Introduction

Osteoarthritis (OA), a painful, debilitating joint disease, often caused by excessive joint stress, is a leading cause of disability (World Health Organisation, 2003) and increases with age and obesity. A 5° varus malalignment increases loading in the medial knee compartment from 70% to 90% (Tetsworth and Paley, 1994). Internal unloading implants, placed subcutaneously upon the medial aspect of the knee joint, are designed to offload the medial compartment of the knee without violating natural joint tissues. The **aim** of this study is to investigate the effect of an unloading implant, such as the Atlas™ knee system, on stress within the tibiofemoral joint with different grades of cartilage defects.

Methods

To simulate surgical treatment of medial knee OA, a three-dimensional computer-aided design of an Atlas™ knee system was virtually fixed to the medial aspect of a validated finite element knee model (Mootanah, 2014), using CATIA v5 software (Dassault Systèmes, Velizy Villacoublay, France). The construct was meshed and assigned material properties and boundary conditions, using Abaqus finite element software (Dassault Systèmes, Velizy Villacoublay, France). A cartilage defect was simulated by removing elements corresponding to 4.7 mm^2. The international cartilage repair society (ICRS) Grade II and III damage were simulated by normalized defect depth of 33% and 67%, respectively. The femur was mechanically grounded and the tibia was subjected to loading conditions corresponding to the stance phase of walking of a healthy 50-year-old 68-Kg male with anthropometrics that matched those of the cadaver. Finite element analyses were run for peak shear and von Mises stress in the medial and lateral tibiofemoral compartments.

Results

Figure 1 shows von Mises stress distribution in the tibial cartilage, with ICRS Grade II and III defects , without the unloading implant, at the end of weight acceptance (15% of the gait cycle). The internal unloading implant reduces peak von Mises stress by 40% and 43% for Grade II and Grade III cartilage defects, respectively. The corresponding reductions in shear stress are 36% and 40%. Figures 2a and 2b show a consistent reduction in peak von Mises stress values in the medial cartilage-cartilage and cartilage-meniscus contact areas throughout the stance phase of the gait cycle for ICRS Grade II defect. Similar results were obtained for Grade III defect and for peak shear stress values. There were no overall increases in peak von Mises stress values in the lateral tibial cartilage.

Discussion and Conclusions

The internal unloading implant is capable of reducing von Mises and shear stress values in the medial tibial cartilage with ICRS Grade II and III defects at the cartilage-cartilage and cartilage-meniscus interfaces throughout the stance phase of the gait cycle. This did not result in increased stress values in the lateral tibial cartilage. Our model did not account for the viscoelastic effects of the cartilage and meniscus. Results of this study are based on only one knee specimen.

The internal unloading implant may protect the cartilage in individuals with medial knee osteoarthritis, thereby delaying the need for knee replacements.

Figures

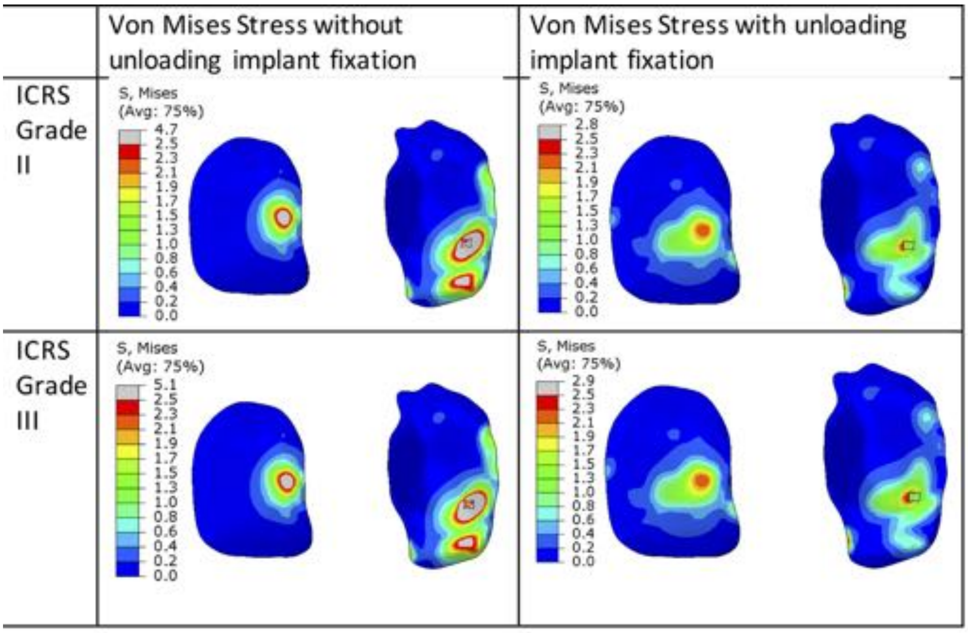

Figure 1

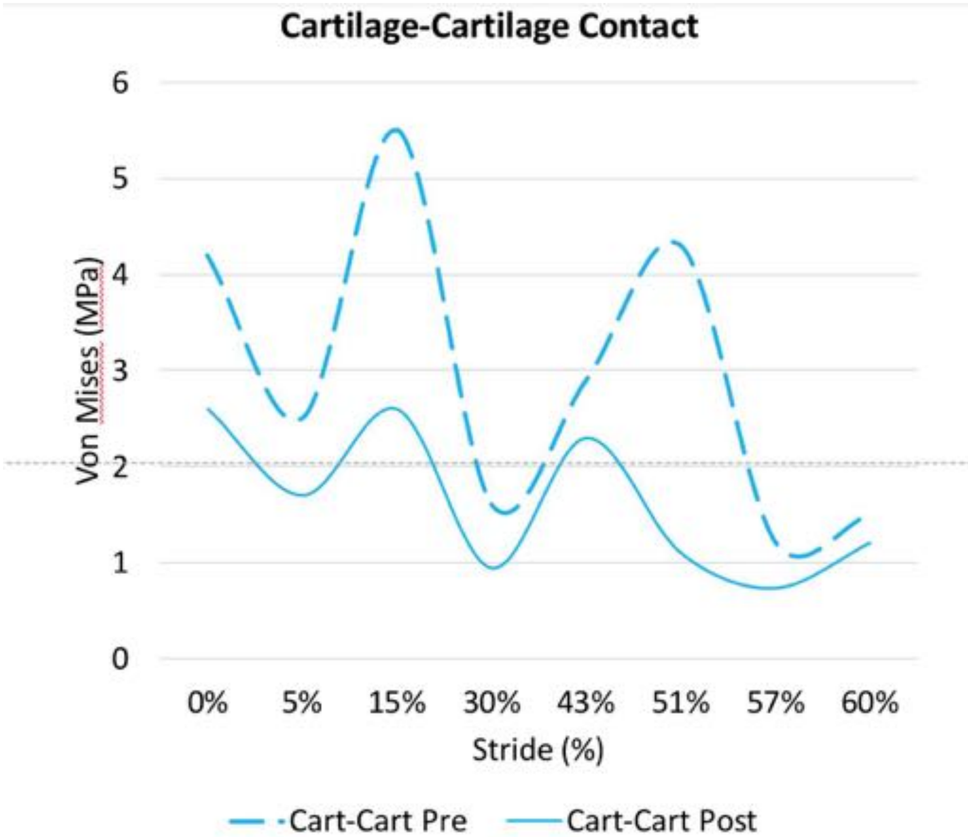

Figure 2

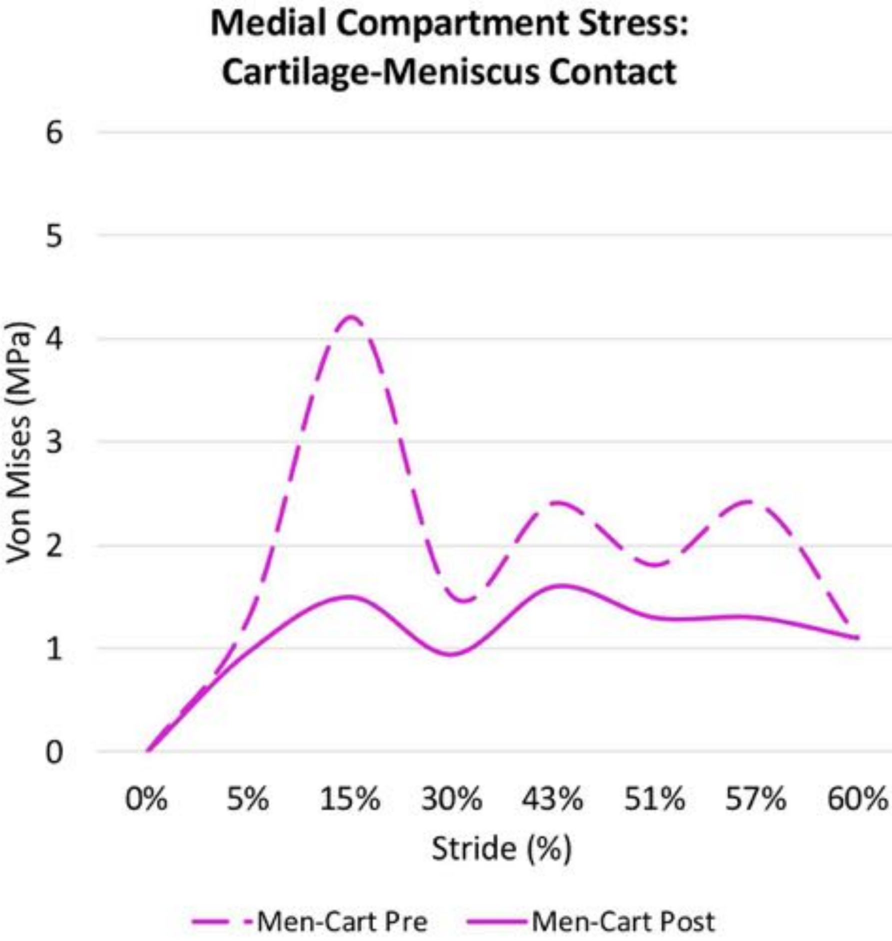

Figure 3

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Figure 4

#6204

Femoral Stress Fractures at Tracker of Computer Navigated Total Knee Replacement and Minimally Invasive Plate Osteosynthesis

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Background:

Stress fractures at tracker after computer navigated total knee replacement are rare. Periprosthetic fracture after Minimally Invasive Plate Osteosynthesis (MIPO) of stress fracture through femoral tracker is unique in orthopaedic literature. We are reporting this unique presentation of periprosthetic fracture after MIPO for stress fracture involving femoral pin site track in computer assisted total knee arthroplasty, treated by reconstruction nail (PFNA).

Methods:

A 75-year old female, who had computer navigated right total knee replacement, was admitted 6 weeks later with increasing pain over distal thigh for 3 weeks without trauma. Prior to onset of pain, she achieved a range of movements of 0-105 degrees. Perioperative radiographs did not suggest obvious osteoporosis, pre-existent benign or malignant lesion, or fracture. Radiographs demonstrated transverse fracture of distal third of femur through pin site track. We fixed the fracture with 11-hole combihole locking plate by MIPO technique. Eight weeks later, she was readmitted with periprosthetic fracture through screw hole at the tip of MIPO Plate and treated by Reconstruction Nail (PFNA), removal of locking screws and refixation of intermediate segment with unicortical locking screws. Then she was protected with plaster cylinder for 4 weeks and hinged brace for 2 months.

Results:

Retrograde nail for navigation pin site stress fracture entails intraarticular approach with attendant risks including scatches to prosthesis and joint infection. So we opted to fix by MIPO technique. Periprosthetic fracture at the top of MIPO merits fixation with antegrade nail in conjunction with conversion of screws in the proximal part of the plate to unicortical locking screws. Overlap of at least 3cms offers biomechanical superiority. She made an uneventful recovery and was started on osteoporosis treatment, pending DEXA scan.

Conclusion:

Reconstruction Nail (PFNA), refixation of intermediate segment with unicortical locking screws constitutes a logical management option for the unique periprosthetic fracture after MIPO of stress fracture involving femoral pin site track in computer assisted total knee replacement.

#5686

What Factor Decides the Posterior Slope Angle of the Tibial Articular Surface?

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Purpose:

Proximal tibiae have various posterior slope angles of the tibial articular surface according to each individual (Fig. 1). The purpose of this study was to clarify the factor to decide the posterior slope angle.

Materials and methods:

101 patients who underwent TKA had lateral view knee digital radiograph. Three lines were drawn on the proximal tibia (Fig. 2). Line 1 represented the anterior cortex of the tibial shaft. Line 2 represented the anterior wall of the tibial condyle. Line 3 represented the medial articular surface. Three angle parameters were measured. Angle APS (articular surface posterior slope) was the angle between the line perpendicular to Line 1 and Line 3. Angle AWA (anterior wall angle) was the angle between Line 1 and Line 2. Angle CAA (condyle and articular surface angle) was the angle between Line 2 and Line 3.

Results:

The mean (±SD) Angle APS, Angle AWA and Angle CAA was 9.4Ëš ± 4.2Ëš, 14.9Ëš ± 6.4Ëš and 95.5Ëš ± 5.5Ëš, respectively. The correlation coefficient between Angle APS and Angle AWA and between Angle APS and Angle CAA was 0.52 and -0.17, respectively. Angle AWA significantly contributed to Angle APS. No correlation was found between Angle APS and Angle CAA.

Discussion:

The result clearly showed that the posterior slope of the tibial articular surface is created by the posterior rotation of the tibial condyle. The average Angle CAA was more than 90 degrees. The proximal tibial condyle does not have a posterior slope. The posterior rotation of the tibial condyle creates the posterior slope of the articular surface relative to the tibial shaft. In the coronal plane, even normal proximal tibiae have varus alignment created by the so called “constitutional varus”. According to this theory, the posterior rotation of the tibial condyle can be called “constitutional posterior rotation”.

This posterior rotation of the tibial condyle involves posterior shift of the tibial articular surface (Fig. 3). Therefore, the anatomical axis that is the central line of the tibial shaft does not coincide the mechanical axis that is defined as the line between the center of the tibial articular surface and the center of the plafond (ankle joint). In this condition, it may be hard to control the tension of the PCL during TKA because the PCL locates posteriorly.

During TKA, no consensus has been obtained for the optimal posterior slope angle of the tibial component. In the coronal plane, the normal medial inclination of the tibial articular surface has been reported as three degrees. In the sagittal plane, the normal posterior rotation angle of the tibial condyle should be clarified. Then, the optimal posterior slope of the tibial component would be decided. PS-TKA may be suitable for knees with larger posterior slope. The other discussion is how to manage the posterior shift of the tibial articular surface. The reduction osteotomy can be applied to the posterior condyle. The concept of "constitutional posterior rotation" can open the new method to decide the alignment of the tibial component in the sagittal plane.

Figures

Figure 1

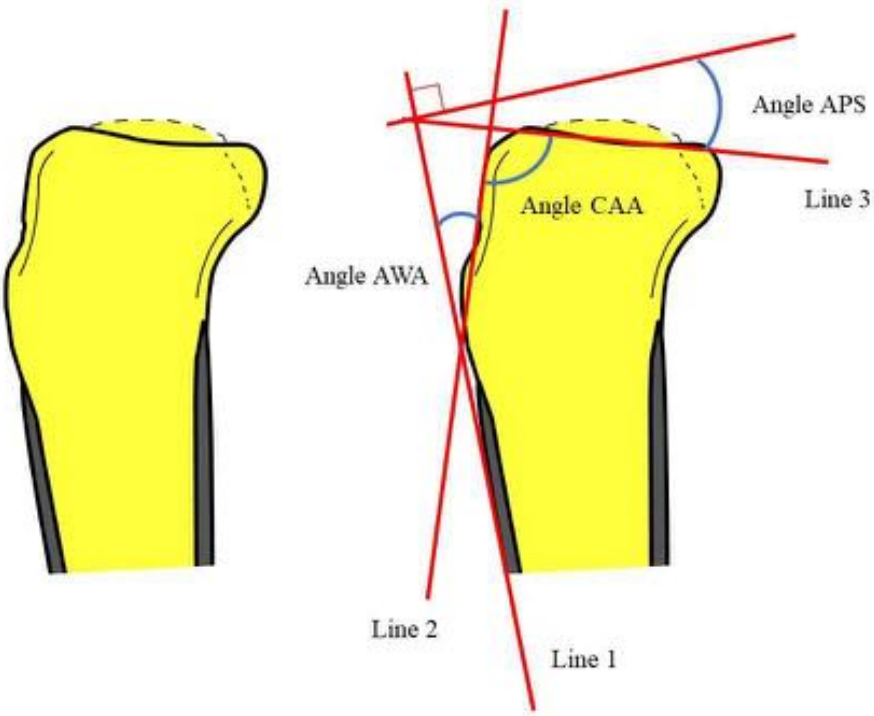

Figure 2

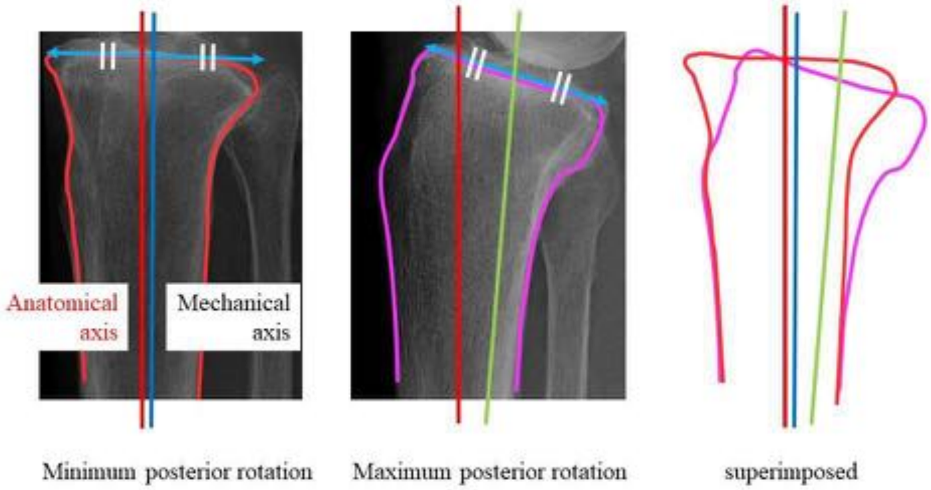
Anatomical axis
Mechanical axis
Minimum posterior rotation
Maximum posterior rotation
superimposed

Figure 3

#6100

Evaluation of Proximal Tibia Bone Quality With Teriparatide Administration by Computed Tomography Number

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BACKGROUND: Proximal tibia bone quality is considered to be one of factors affecting the outcome after total knee arthroplasty (TKA), and teriparatide has been administrated to improve the quality of the surgical site bone. However, the improvement has evaluated by parameters such as bone metabolism marker (e.g. P1NP) and dual-energy X-ray absorptiometry at hip and spine, and therefore the surgical site is not necessarily assessed. We investigated Hounsfield Unit (HU), or a computed tomography number, of non-operative side proximal tibia in patients with injection of teriparatide after TKA on only one side.

METHODS: Twenty-eight women (mean age, 76.2 years) who underwent TKA with injection of teriparatide for at least 6 months (mean duration of injection, 15.9 months) were included in this study. HU of the proximal tibia on non-operative side at the most proximal level of fibular head (proximal surface) and at 5 mm below (distal surface) were measured at pre-op, 6 months and the end of injection therapy using computed tomography.

RESULTS: We observed an average of HU of 105.3, 110.5 and 116.3 on the proximal surface, and 75.1, 79.7 and 85.7 on the distal surface at pre-op, 6 months and â€€the end of the therapy, respectively. In any period, these values increased, however, no significant difference was detected.

DISCUSSION: We had reported the decrease of bone density, assessed by X-ray, under tibia component after TKA without teriparatide administration.Some similar reports regard the decrease as a result of shear-stress shielding or a systemic hyper bone turnover after the operation. This study, focusing non-operative side, was intended to foreclose such a post-operative impact. Though, we hypothesized this study showed some significant difference, the truth of the matter was that there was no difference. We suggest that the teriparatide administration made at least the bone quality maintained. The limitation of this study is not to mention control group, and then we need further study looking at the case series without teriparatide administration in the same way.

CONCLUSION: Teriparatide injection after TKA maintained the Hounsfield Unit (HU) of non-operative side proximal tibia.

#6044

Pre-Operative Anatomy and Its Correlation to Intra-Operative Knee Laxity and Patient Outcome in Total Knee Arthroplasty

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Introduction

Variation in resection thickness of the femur in Total Knee Arthroplasty (TKA) impacts the flexion and extension tightness of the knee. Less well investigated is how variation in patient anatomy drives flexion or extension tightness pre- and post- operatively. Extension and flexion stability of the post TKA knee is a function of the tension in the ligaments which is proportional to the strain. This study sought to investigate how femoral ligament offset relates to post-operative navigation kinematics and how outcomes are affected by component position in relation to ligament attachment sites.

Method

A database of TKA patients operated on by two surgeons from 1-Jan-2014 who had a pre-operative CT scan were assessed. Bone density of the CT scan was used to determine the medial and lateral collateral attachments. Navigation (OmniNav, Raynham, MA) was used in all surgeries, laxity data from the navigation unit was paired to the CT scan. 12-month postoperative Knee Osteoarthritis and Outcome Score (KOOS) score and a postoperative CT scan were taken. Preoperative segmented bones and implants were registered to the postoperative scan to determine change in anatomy.

Epicondylar offsets from the distal and posterior condyles (of the native knee and implanted components), resections, maximal flexion and extension of the knee and coronal plane laxity were assessed. Relationships between these measurements were determined. Surgical technique was a mix of mechanical gap balancing and kinematically aligned knees using Omni (Raynham, MA) Apex implants.

Results

119 patients were identified in the database. 60% (71) were female and the average age was 69.0 years (+/- 8.1). The average distal femoral bone resection was 7.5 mm (+/- 1.6) medially and 5.4 mm (+/- 2.1) laterally, and posterior 10.2 mm (+/- 1.7) medially and 8.4 mm (+/- 1.8) laterally, with implant replacement thicknesses 9 mm distally and 11 mm posterior. Maximum flexion of the knee post implantation was 121.5° (+/- 8.1) from a preoperative value of 117.9° (+/- 9.5).

Change in the collateral ligament offsets brought on by surgery had significant correlations with several laxity and flexion measures. Increase in the posterior offset of the medial collateral attachment brought on by surgery was shown to decrease the maximum flexion attained (coefficient = -0.53, $p < 0.001$), Figure 1. Increased distal medial offset post-operatively compared to the posterior offset is significantly correlated with improved KOOS pain outcomes (coefficient = 0.23, $p = 0.01$). Similarly, a decrease in the distal offset of the lateral collateral ligament increased the coronal plane laxity in extension (coefficient = 0.37, $p < 0.001$), while the posterior lateral resection was observed to correlate with postoperative coronal laxity in flexion (coefficient = 0.42, $p < 0.001$).

Conclusions

Accounting for variation in ligament offset during surgically planning may improve balancing outcomes. Although new alignment approaches, such as kinematic alignment, have been able to demonstrate improvements in short term outcomes, elimination of postoperative dissatisfaction has not been achieved. The interaction of an alignment strategy with a given patient's specific anatomy may be the key to unlocking further TKA patient outcome gains.

Figures

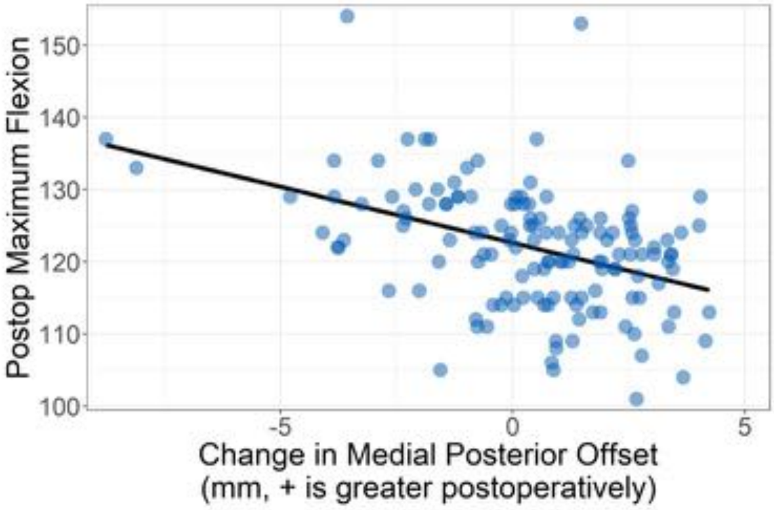

Figure 1 Increasing the posterior offset of the medial collateral ligament results in reduced maximum flexion post-operatively.

Figure 1

#6144

Numerical Analysis of the Knee Cartilage With Resultant Joint-Line Obliquity

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[Introduction] Although total knee replacement became a widespread procedure for the purpose of knee reconstruction, osteotomies around the knee were regularly performed. Total knee arthroplasty should be performed for advanced arthritis of the knee. With the advent of biplanar open wedge high tibial osteotomy (HTO) combined with locking plate fixation, HTO has been expanded and its surgical outcome has been improved in recent years. However, post-operative joint-line obliquity has been raised as a concern with this procedure, which may affect the outcome especially in the knees with severe varus deformity. Hence the purpose of this study is to analyze the compression and shear stresses in the knee cartilage with joint line obliquity after HTO. [Methods] Using a three-dimensional computer aided design software, the digital knee model with soft tissues was developed. The geometrical bone data used in this study were derived from commercially available human bone digital anatomy media (3972 and 3976, Pacific Research Laboratories, Inc., WA, USA). The three-dimensional knee model was transferred to finite element model. Material properties of the soft tissues and bones were derived from the literature [1]. The loading condition was adjusted to the load during a single-leg stance of the gait cycle, which resulted in an axial compressive load of 1200 N [14]. Two different conditions were subjected to the analysis: normal alignment and joint-line obliquity after HTO. For the normal alignment, a static force of 1200 N was applied along the mechanical axis. For the joint-line obliquity models, a single force of 1200 N was applied rotating force directions in the frontal plane from the normal direction by 2.5º, 5º, 7.5º, and 10º, respectively. [Results] The maximum values of the axial stresses in the cartilages for the normal condition showed almost same values in medial and lateral compartments. In the joint-line obliquity models, the maximum axial stress values in the medial compartment did not exhibit substantial change up to the level of 7.5º obliquity, while a rise in maximum stress value was observed for the model with 10º obliquity. The shear stress showed a different tendency. In the joint-line obliquity models, a steep rise of laterally directed shear stress in the medial compartment was observed for models with obliquity of 5º or more. [Discussion] The shear stress in the medial cartilage increased to almost twice as high as the normal knee level for the joint-line obliquity model with an inclination of 5º. The maximum shear stress values increased in accordance with the obliquity angle. The elevated stress could be deleterious to the cartilage. In such large amount of correction by tibial osteotomy leads to unfavorable mechanical environment in the knee. For those severe situations, double-level osteotomy, which retains anatomical knee joint line by simultaneous femoral and tibial osteotomies, should be considered to correct the joint-line obliquity.

[1] Andriacchi TP, Mikosz RP, Hampton SJ, Galante JO (1983), Model studies of the stiffness characteristics of the human knee joint. J Biomech 16:23–29

#5674

Examination of the Relationship Between the Axial CT Shape of Distal Femoral Condyle Osteotomy and the Implant Shape in Total Knee Arthroplasty

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ã€Backgroundã€‘We sometimes have experienced a case which the transverse diameter of femoral implant is smaller than that of condylar part with osteotomy when TKA is performed and reffered with anteroposterior diameter in daily clinical practice. We presume the difference is related to the difference between the morphological features of Japanese knee and the implant form actually used.

ã€Purposeã€‘We aim to investigate the the axial CT shape of distal femoral condyle osteotomy and to compare with the used implant shape in Total Knee Arthroplasty at our hospital. ã€Material and Methodã€‘ We examined 110 knees 93 people who underwent TKA with PFC Σ at our hospital from January 2010 to December 2016. They were male 18 cases 21 knees and female 75 cases 89 knees. The mediallateral diameter (ML) of the axial CT of distal femoral condyle osteotomy were measured by selecting the maximum diameter. The anteroposterior diameter (AP) were measured the distance from the deepest part of the patella groove to the posterior condylar line in the same as ML slice. We calculated the height, weight, ML and AP diameter, aspect ratio (AP/ML) and examined the correlation and comparison the female group with the male group.

ã€Resultã€‘Average ML diameter of the male were 75.93 mm, the female was 67.76 mm, and the male was significantly larger than male ($p = 7.4 \times 10^{-17}$) . Average AP diameter of the male was 48.83 mm, the female was 46.74 mm, and the male was significantly larger than male ($p = 0.01$). But average aspect ratio of the male was 0.64, the female was 0.69 and the female was significantly greater than male ($p = 3.4 \times 10^{-5}$). There was a positive correlation between both height and body weight and ML diameter, ML diameter and AP diameter ($r = 0.5985$, $r = 0.4618$, $r = 0.4733$), the ML diameter and the aspect ratio showed a negative correlation ($r = - 0.4559$) and these strength of the correlation tended to be stronger for men with $r= -0.3241$ than female with $r=-0.728$. ML diameter in AP diameter comparable (45-50mm) cases significantly greater in males ($p = 3.8 \times 10^{-7}$) , aspect ratio was significantly greater in female ($p = 2.0 \times 10^{-5}$) .

ã€Discussionã€‘ From the present study, it was revealed that aspect ratio of axial CT shape of distal femoral condyle osteotomy becomes smaller as increase in lateral diameter male and female. However, almost of European and American femoral implants including PFCΣ are not such a form and the difference was revealed.

ã€Summaryã€‘ It became obvious that the axial CT shape of distal femoral condyle osteotomy becomes flat as the lateral diameter becomes larger, and the difference with PFC Σ femoral implant was clarified.

#5942

Predisposing Factors for Patellofemoral Arthritis and Their Correction After Patellofemoral Arthroplasty

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Background

The goal of patellofemoral arthroplasty (PFA) is to replace damaged cartilage, and to correct underlying deformities, to reduce pain and prevent maltracking. We aimed to determine how PFA modifies patellar height, tilt, and tibial tuberosity to trochlear groove (TT-TG) distance. The hypothesis was that PFA would correct trochlear dysplasia or extensor mechanism malalignment.

Methods

The authors prospectively studied a series of 16 patients (13 women and 3 men) aged 64.9 ± 16.3 years (range, 41 to 86) that received PFA. All knees were assessed pre-operatively and six months post-operatively using frontal, lateral, and ‘skyline’ x-rays, and CT scans to calculate patellar tilt, patellar height and tibial tuberosity–trochlear groove (TT-TG) distance.

Results

The inter-observer agreement was excellent for all parameters. (ICC > 0.95). Pre-operatively, the median patellar tilt without quadriceps contraction (QC) was 17.5° (range, 5.3°–33.4°) and with QC was 19.8° (range, 0°–52.0°). The median Caton-Deschamps Index (CDI) was 0.91 (range, 0.80–1.22) and TT-TG distance was 14.5mm (range, 4.0–22.0). Post-operatively,the median patellar tilt without QC was 0.3° (range, -15.3°–9.5°) and with QC was 6.1° (range, -11.5°–13.3°). The median CDI was 1.11 (range, 0.81–1.20) and TT-TG distance was 10.1mm (range, 1.8–13.8mm).

Conclusion

The present study demonstrates that, beyond replacing arthritic cartilage, trochlear-cutting PFA improves patellofemoral congruence by correcting trochlear dysplasia and standardizing radiological measurements as patellar tilt and TT-TG. The association of lateral patellar facetectomy diminishes local effects of OA and improves patellar tracking by reducing the patellar tilt.

#5810

What Is the Prevalence of Femoral Component Overhang in Total Knee Arthroplasty?

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Introduction: While TKA procedures have demonstrated clinical success, medial/lateral overhang of the femoral component in total knee arthroplasty (TKA) of ≥3mm has been shown to be associated with an increased risk of knee pain [1]. The Asian patient population tends to have a smaller distal femoral size, as compared to the Caucasian population [2]. The aim of this study was to determine and compare the prevalence of femoral component overhang among an inclusive (non-segmented) and Asian-identified (Asian-segmented) population, using a flexible intramedullary-rod, posterior referencing method.

Methods: CT Scans from bilateral lower limbs of skeletally mature subjects (981 inclusive, 267 Asian-identified), without bone pathology were prospectively acquired. Bones were segmented and landmarks were modeled using a flexible intramedullary-rod, posterior referencing method. Femoral components were virtually positioned by aligning the lateral implant edge with the lateral bone edge, where the anterior flange meets the anterior chamfer [Fig. 1]. Medial and lateral component overhang was measured at three zones: (1) intersection of the anterior flange and anterior chamfer (medial only), (2) anterior chamfer mid-line, and (3) distal face mid-line [Fig. 2]. The central tendency of the samples was determined using the observed mean and median and the 95% confidence interval.

Results: In this study, the percentages of the inclusive population that had predicted fit with overhang <3mm were 98.9% at Zone 1 (medial), 99.7% and >99.9% at Zone 2, and 99.2% and 98.4% at Zone 3, for medial and lateral measurements, respectively [Fig. 3]. The percentages of the Asian-identified population with predicted overhang <3mm were 98.4% at Zone 1 (medial), 99.6% and >99.9% at Zone 2, and 99.1% and 98.3% at Zone 3, for medial and lateral measurements, respectively.

Discussion and conclusion: This virtual study demonstrates the femoral components of this knee system are predicted to fit over 98.3% of the inclusive and Asian-identified population with overhang less than 3mm, using a flexible intramedullary-rod, posterior referencing method. When evaluating the fit of an implant, it is important to match the implant placement per the design intent of the system. A separate study using an alternate referencing method, without the use of a flexible intramedullary-rod, showed up to an 8% difference in predicted successful fit, as compared to the findings in the present study [3]. Fit studies should be cautiously interpreted and consider design intent of the system.

References:

[1] Mahoney OM, Kinsey T. Overhang of the femoral component in total knee arthroplasty: risk factors and clinical consequences. J Bone Joint Surg Am. 2010 May;92(5):1115-21.

[2] Mahfouz M, Abdel Fatah EE, Bowers LS, Scuderi G. Three-dimensional morphology of the knee reveals ethnic differences. Clin Orthop Relat Res. 2012 Jan;470(1):172-85.

[3] Dai Y, Scuderi GR, Penninger C, Bischoff JE, Rosenberg A. Increased shape and size offerings of femoral components improve fit during total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2014 Dec;22(12):2931-40.

Figures

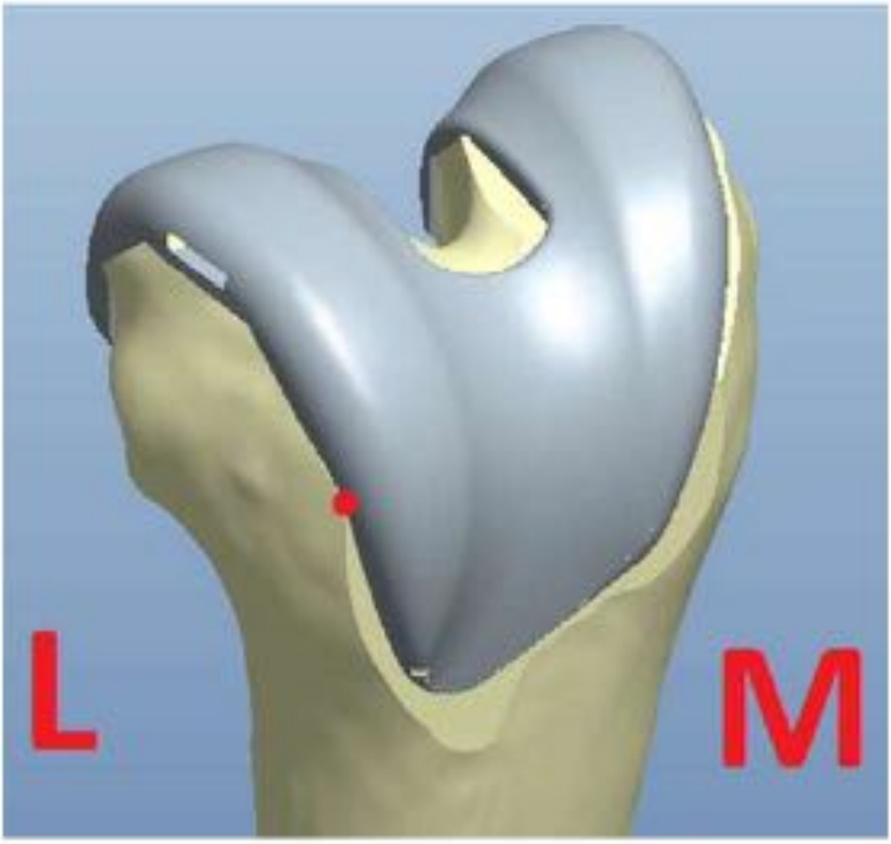

Figure 1. Lateral implant edge virtually aligned with lateral bone edge, where the anterior flange meets the anterior chamfer.

Figure 1

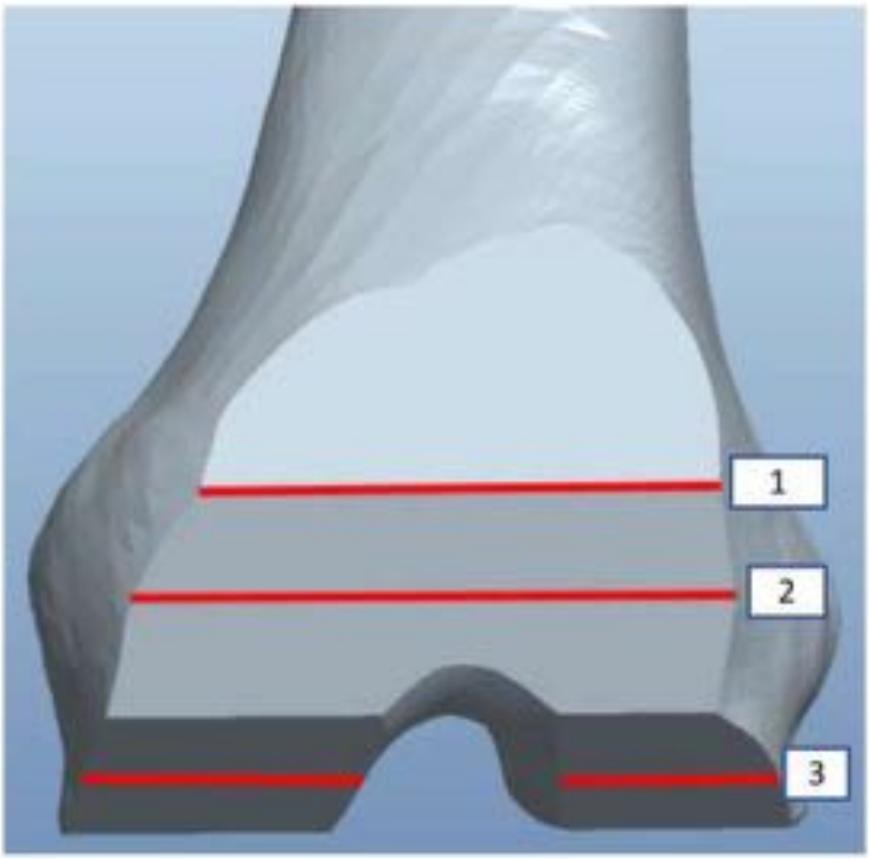

Figure 2. Anterior view of the femoral cuts showing location for measurements at Zone (1) intersection of the anterior flange and anterior chamfer (medial only), (2) anterior chamfer mid-line, and (3) distal face mid-line.

Figure 2

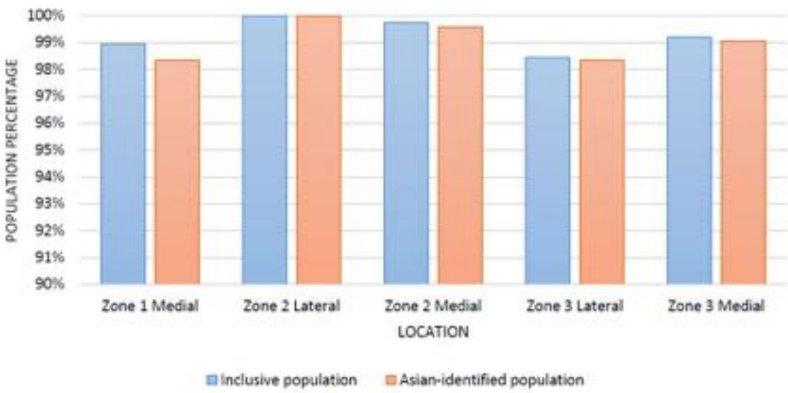

Figure 3. Prediction of percentage of inclusive and Asian-identified population with overhang <3 mm at Zone 1 (medial), 2 (lateral and medial) and 3 (lateral and medial).

Figure 3

#5591

Accuracy of Tibial Slope Estimation in Total Knee Arthroplasty

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Introduction:

Extramedullary referencing guides are commonly used to assist with tibial cuts in total knee arthroplasty. Proper use of such instruments depends upon a surgeon's ability to set such a guide correctly in relation to the patient's tibia. Typical planned posterior slope in the sagittal plane varies from 0 to 7 degrees based on implant design and surgeon preference. While many tibial guides are made that have built in slope, requiring the surgeon to set the guide perpendicular to the long axis of the tibia, others have no built-in slope and the surgeon must therefore estimate the posterior slope prior to making the tibial cut. This study analyzes the ability of training and experienced orthopedic surgeons to estimate both 0 and 5 degrees of posterior slope.

Methods:

Prospective data was collected from resident and faculty orthopedic surgeons at a single institution. A model knee was used with navigational equipment attached to an extramedullary tibial cutting guide (figures 1 and 2). Participants were asked to alternately estimate 0 and 5 degrees of posterior slope with sets of 20 data points collected in a single run. Participants repeated the exercise for 3 trials over the course of 2 days and were blinded to the accuracy of their measurements. Data was stratified according to training level and statistics performed via regression analyses and odds ratios with significance set at $p<0.05$.

Results:

Median values for estimations of 0 and 5 across all groups equaled 1(upper and lower quartiles of 0,2) and 3(2,5) respectively. There was a tendency for surgeons to err towards increased slope in the 0 group and decreased slope in the 5 group. Overall there was no difference in the variation of measurements from the targets of 0 and 5 ($P=0.220$). Participants were more likely to estimate exactly 0 than exactly 5 ($P=0.003$). and there was a positive correlation between training and accuracy specifically in the 0 degree slope group with experienced surgeons more likely to closer to 0 than other training levels (OR 2.09-8.44). Lastly, the ability to produce an intended 5 degree difference in estimated slope increased with surgeon experience (figure 3).

Conclusion:

In our analysis of orthopedic surgeons at various training levels in a single institution, participants more accurately estimated 0 degrees of slope than 5 degrees of slope. This finding may have clinical significance as guides with built-in slope (therefore requiring an estimation of 0 degrees) may more consistently produce the intended result.

Figures

Figure 1

Figure 2

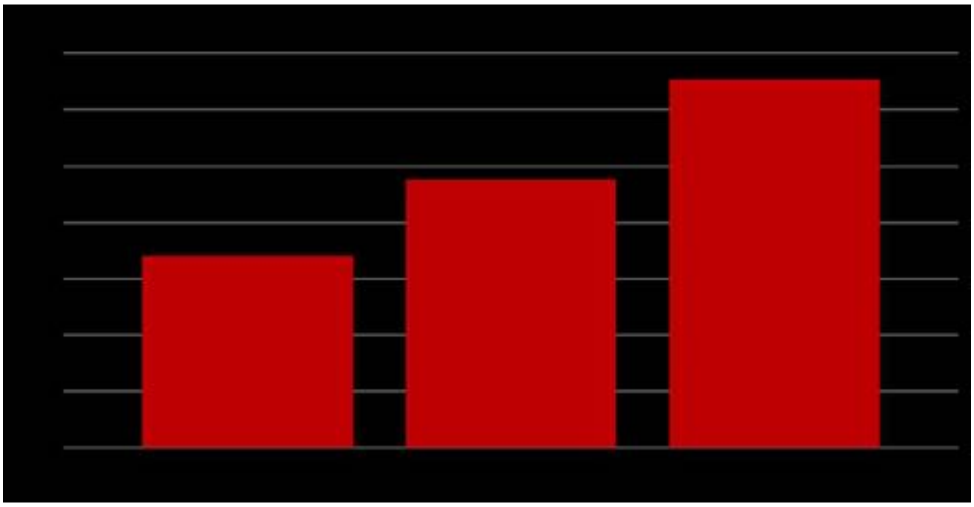

Figure 3

#5944

External Rotation of the Femoral Component Increases Asymmetry of the Posterior Condyles

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Aims: The morphometry of the distal femur was largely studied to improve bone-implant fit in total knee arthroplasty (TKA), but little is known about the asymmetry of the posterior condyles. This study aimed to investigate the dimensions of the posterior condyles and the influence of externally rotating the femoral component on potential prosthetic overhang or under-coverage.

Methods: We analysed the shape of 110 arthritic knees at the time of primary TKA using pre-operative CT scans. The height and width of each condyle were measured at the posterior femoral cut in neutral position, and in 3º and 5º of external rotation, using both central and medial referencing systems (Fgirue 1). We compared the morphological characteristics with those of 14 TKA models.

Results: In the neutral position, the dimensions of the condyles were nearly equal. Externally rotating the femoral cut by 3º and 5º with ‘central referencing’ induced width asymmetry >3mm in 23% and 32% of knees, respectively, while with ‘medial referencing’ it induced width asymmetry >3mm in 41% and 68% of knees, respectively. The asymmetries induced by rotations were not associated with gender, aetiology or varus-valgus alignment.

Discussion: External rotation could amplify the asymmetry between the medial and lateral condyles, and exacerbate prosthetic overhang, particularly in the supero-lateral zone. ‘Central referencing’ guides result in less potential prosthetic overhang than ‘medial referencing’ guides.

Take Home Message: Surgeons must be aware of prosthetic overhang that could arise at the posterior condyles, which are hardly visible during surgery, and which could induce impingements with the popliteus tendon or the joint capsule.

Figures

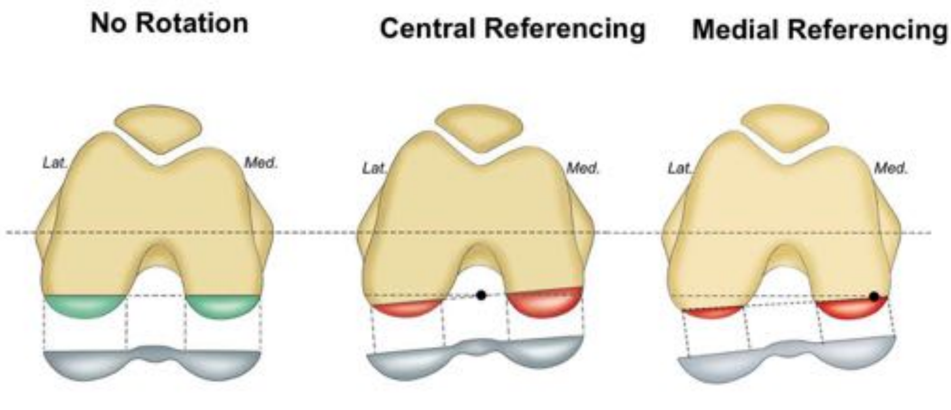

Figure 1

#5920

Tibial Bone Density Changes Following TKA: What Can We Learn From DEXA Studies?

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Introduction

Aseptic loosening is the main reason for total knee arthroplasty (TKA) failure, responsible for more than 25% of the revision procedures, with most of the problems occurring with the tibial component. While early loosening can be attributed to failure of primary fixation, late implant loosening is associated with loss of fixation secondary to bone resorption due to altered physiological load transfer to the tibial bone. Several attempts have been made to investigate these changes in bone load transfer in biomechanical simulations and bone remodeling analyses, which can be useful to provide information on the effect of patient, surgery, or design-related factors. On the other hand, these factors have also been investigated in clinical studies of radiographic changes of bone density following TKA. In this study we made an overview of the knowledge obtained from these clinical studies, which can be used to inform clinical decision making and implant design choices.

Methods

A literature search was performed to identify clinical follow-up studies that monitored peri-prosthetic bone changes following TKA. Within these studies, effects of the following parameters on bone density changes were investigated: post-operative time, region of interest, alignment, body weight, systemic osteoporosis, implant design and cementation. Moreover, we investigated the effect of bone density loss on implant survival.

Results

A total of 19 studies was included in this overview, with a number of included patients ranging from 12 to 7,760. Most studies used DEXA (n=16), while a few studies performed analyses on calibrated digital radiographs (n=2), or computed tomography (n=1). Postoperative follow-up varied from 9 months to 10 years.

Studies consistently report the largest bone density reduction within the first postoperative year. Bone loss is mainly seen in the medial region. This has been attributed to the change in alignment following surgery, during which often the pre-operative varus knee is corrected to a more physiological alignment, resulting in a load shift towards the lateral compartment. Measurements in unoperated contralateral legs were performed in 3 cases, and two studies performed standardized DEXA measurements to provide information on systemic osteoporosis. While on the short term no changes were observed, significant negative correlations have been found between severity of osteoporosis and periprosthetic bone density. No clear effects of bodyweight and cementation on bone loss have been identified. Although some studies do find differences between implant types, the variation in the data makes it difficult to draw general conclusions from these findings.

Several studies reported no effect of bone loss on implant migration. In another study, a medial collapse was associated with a medial increase in density, suggesting that altered loading and increased stresses are responsible for both bone formation and the overload leading to collapse.

Discussion

There are important lessons to be learned from these clinical studies, although generally the large spread in the DEXA data restricts strong conclusions. There is a large variation in used ROI definitions, complicating direct comparisons. Finally, most studies report density changes of well-functioning reconstructions, since only very large studies are able to gather enough failed cases.

#5574

Comprehensive Femoral Component Fit Assessment on Mediolateral Overhang and Sulcus Restoration

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INTRODUCTION

Proper fit of the implants with the native morphology in the knee is critical to the success of total knee arthroplasty (TKA). In the femur, achieving this goal requires consideration of minimizing mediolateral (ML) overhang of the femoral implant as well as accurate alignment between the trochlear and the patella for proper patellofemoral kinematics. Both considerations can be influenced by the design of the femoral component. This study accessed the femoral component of a newly released knee design for ML fit and restoration of native trochlear groove at high flexion.

MATERIALS AND METHODS

After obtaining institutional review board approval and informed consent, CT based surface models of 48 Chinese (24M/24F) and 43 Caucasian (22M/21F) right femora was virtually resected according to its proper component size following anterior referencing surgical technique for Truliant® Knee System (Exactech Inc, Gainesville, FL, USA). A computer algorithm first placed and lateralized the femoral component such that it aligned with the bony resection at the anteroposterior (AP) mid-point of the distal cut. The ML fit of the component was then measured at the AP mid-point of the distal resection. The placement was further optimized by slightly adjusting the component ML to reduce the incidence of clinically important overhang (>3mm [1]) and minimized the ML deviation between the center of the component intercondylar notch and the deepest point on native trochlear groove at the same proximal-distal level as the component notch (Fig 1). The fit of the component was assessed by the incidence and severity of clinically important overhang based on the optimized placement, as well as the ML deviation between component and native intercondylar notch locations. A <5mm deviation was considered proper restoration of the notch by the femoral component [2,3]. Significance was defined as $p<0.05$.

RESULTS

Only one out of the 91 bones had >3mm component overhang (chinese, female), with a negligible amount of overhang exceeding the clinically important threshold (0.8mm) (table 1a). The notch of the placed femoral component closely restored the native location, which was on average ~1mm medial to that of the femur across all ethnic and gender groups (table 1b). 95% of the bones had the femoral component notch placed within 5mm ml of the native femoral intercondylar notch. No ethnic or gender difference was found in the deviation of notch location.

DISCUSSION

The findings demonstrated excellent fit offered by the newly released knee design, which not only minimize the component overhang, but also restore the ML position of the native intercondylar notch in the femur. Without offering narrow components, this knee design was shown to provide equally good fit among both ethnic groups studied and both genders. Compared to the reported data on several femoral designs [3,4], the intercondylar notch in this design may offer less patella displacement at high flexion, potentially facilitating normal patella tracking.

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Figures

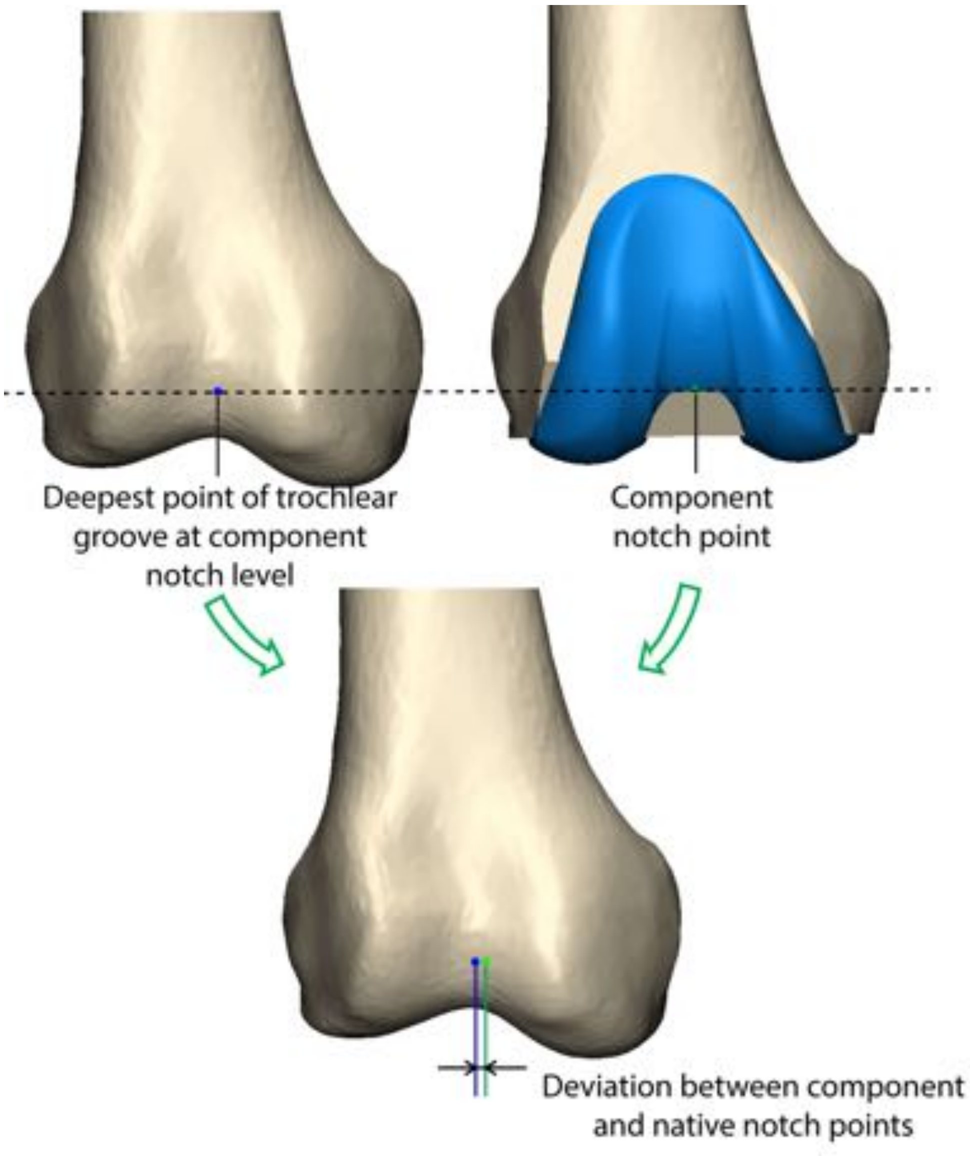

Figure 1. A representative femur demonstrating the measurement of mediolateral deviation between the placed component intercondylar notch and corresponding notch point on the native trochlear groove.

Figure 1

A	Incidence of Clinically Important Overhang			
	Chinese	Caucasian	Female	Male
N	48	43	45	46
Number of Bones with >3mm Overhang	1 (3.8mm)	0	1 (3.8mm)	0

B	Deviation (mm)	p
Pooled	-1.0 ± 1.6	-
Chinese	-1.3 ± 1.9	0.10
Caucasian	-0.7 ± 1.3	
Female	-1.3± 1.9	0.13
Male	-0.8 ± 1.3	

† Negative values indicate that intercondylar notch in the femoral component is medial to the native notch.

Table 1. A) Incidence of >3mm overhang in the data set. B) Mediolateral deviation in the location of intercondylar notch betwen the placed femoral component and the native bone.

Figure 2

#5541

Changes in Bone Mineral Density of Both Proximal Femurs After Total Knee Arthroplasty

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Changes in Bone Mineral Density of Both Proximal Femurs after Total Knee Arthroplasty

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Background:This study investigated the effects of total knee arthroplasty (TKA) on bone mineral density (BMD) of the proximal femur in patients who underwent the procedure.

Methods: Forty-eight patients scheduled to undergo unilateral TKA because of primary knee osteoarthritis were included in this study, which was conducted at a medical center between October 2006 and October 2009. In these 48 patients, 96 hips were evaluated. Measurement of BMD was performed preoperatively and one month, three months, six months, and one year after unilateral TKA. Repeated measured analysis of variance and paired t-tests for comparison of two repeated samples were used to compare differences between time points (preoperation, one, three, six, and 12 months) and between the operative and nonoperative sides.

Results: Preoperatively, BMD of the femoral neck, trochanter, and total hip on the operative side were lower than on the nonoperative side; however, there was no statistical difference. BMD of both femoral neck areas was significantly lower than preoperative BMD at one month and three months after TKA. BMD of both trochanter areas was significantly lower than preoperative BMD at one month and three months after TKA. BMD of both total hips was significantly lower than preoperative BMD at three months after TKA. However, no statistical differences of changes in BMD were observed between the operative and nonoperative sides at each measurement time.

Conclusions: According to our results, TKA was found to affect both proximal femurs during the acute period. However, TKA did not affect a change in BMD of the proximal femur during one year postoperative

#5737

Effect of Soft Tissue Constraints and Component Alignment on the Kinematics and Wear of Total Knee Replacements

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Component alignment and soft tissue constraints are key factors affecting function and implant survival after total knee replacement (TKR). Knee kinematics contribute to knee function whilst soft tissue constraints and component alignment impact polyethylene wear. This study experimentally investigated the effect of soft tissue constraints and component alignment on the kinematics and wear of a TKR.

A six station electromechanical ProSim knee simulator was used with the ISO 14243-1:2009 standard force control inputs; axial force, flexion-extension (FE), tibial rotation (TR) torque and anterior-posterior (AP) force. This allowed the kinematics to vary with the test conditions. The soft tissue constraints were simulated using virtual springs.

DePuy Sigma XLK fixed bearing TKRs were tested in 25% bovine serum (in 0.04% sodium azide) lubricant. The average output kinematics across 6 stations were found for each test and the peak values compared. The wear rates were calculated over 2 million cycles (MC), the serum was changed every 350,000 cycles and the tibial inserts weighed after every MC. A one way ANOVA and post hoc Tukey's test was used to compare the kinematics and wear with significance taken at $p<0.05$.

The kinematics and wear rates for three soft tissue conditions were established under ideal alignment (Table 1). The ISO standard springs for a cruciate substituting (CS) and a cruciate retaining (CR) prosthesis were used to represent a knee with a resected ACL and PCL and a knee with a resected ACL respectively. The third spring condition was based on clinical data to represent a "stiff" knee.

Three other alignment conditions were then assessed using "stiff" knee springs; 4° varus, 14° rotational mismatch and 10° posterior tibial slope. These alignments were chosen to represent the range found in clinical data.

Under ideal alignment the "stiff" knee springs had significantly lower peak AP and TR displacements (0.9mm, 2mm, 2mm and 3.6°, 7.1°, 7.8° for the "stiff", CR and CS springs respectively) than the other springs ($p<0.01$) (Figure 1.1). The "stiff" knee spring had a significantly lower wear rate than the CR spring; 1.58 ±1.20mm³/MC compared to 4.71±1.29 mm³/MC ($p<0.01$).

The varus and rotated components had significantly larger peak AP displacements of 2.56mm and 2.42mm respectively, than the ideal and tibial slope fixtures (1.97mm and 0.92mm respectively) ($p<0.01$) (Figure 1.2). The rotated components had significantly higher internal rotation of 12.2° compared to 4.4°, 3.7° and 3.5° for the tibial slope, varus and ideal components respectively ($p<0.01$).

The ideal and varus components had significantly lower wear than the tibial slope and rotated components (1.58±1.20mm³/MC and 0.15±0.83mm³/MC compared to 8.24±7.72mm³/MC and 5.19±1.12mm³/MC respectively) ($p<0.01$). This may be due to increased AP and TR displacements with the rotated components and the increased anterior AP displacement with the tibial slope components, resulting in wear on the posterior edge of the tibial insert.

Soft tissue constraints and component alignment had a significant effect on the kinematics and wear. Experimental simulation should test a variety of soft tissue and alignment conditions to reflect the range observed clinically and determine causes for early failure.

Figures

Table 1: Spring tension values for the three spring conditions tested

Springs	AP Spring			TR Spring	
	Gap Around the Zero Position (mm)	Anterior Spring Tension (N/mm)	Posterior Spring Tension (N/mm)	Gap Around the Zero Position (°)	Spring Tension (Nm/°)
ISO CR	2.5	9.3	44	6	0.36
ISO CS	2.5	9.3	9.3	6	0.13
"Stiff" knee	0	127	127	0	0.7

[Figure 1](#)

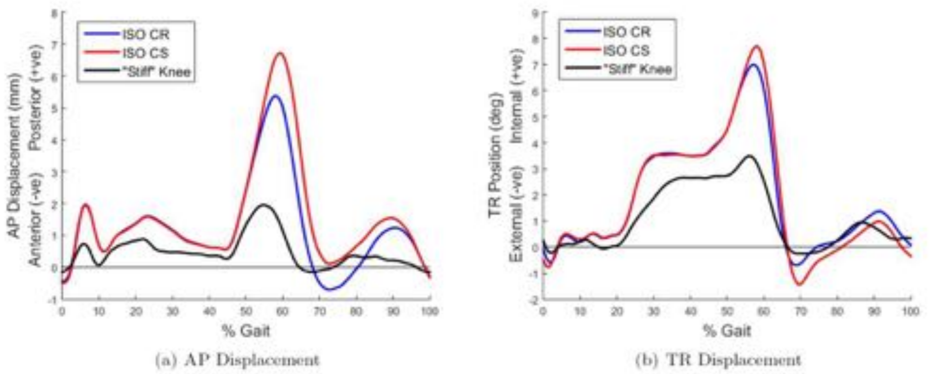

Figure 1.1: Average output kinematics with ideal alignment and three different soft tissue conditions

[Figure 2](#)

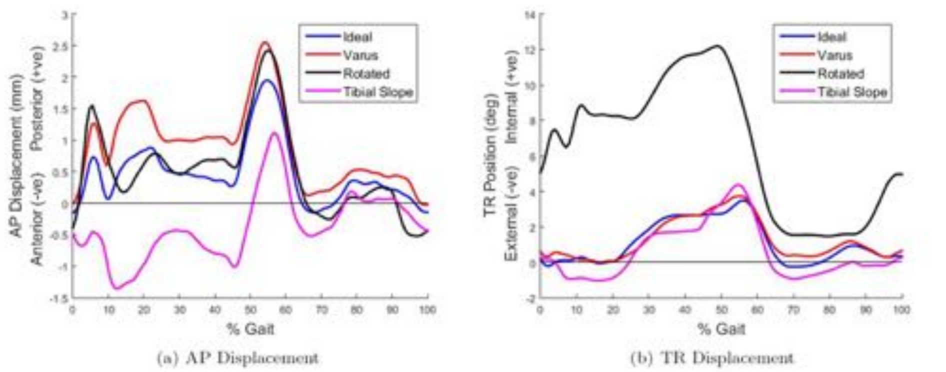

Figure 1.2: Average output kinematics using "stiff" knee springs and four different alignment conditions

[Figure 3](#)

#5509

Comparison of Contact Pressure on the Anterior Aspect of the Knee During Kneeling Between Volunteers and Postoperative Patients.

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Introduction

Kneeling pain in patients who have undergone TKA has various potential sources, including scar position, pain-sensing mechanoreceptors, patellofemoral joint pressure, and contact pressure. Among these risk factors, we hypothesized that high contact pressure on the anterior aspect of the knee contributes to pain or discomfort during kneeling after undergoing TKA. In order to investigate whether the contact pressure is related to the pain at the time of kneeling, it is first necessary to establish a method for quantitatively measuring the contact pressure. Thus, our study aimed to quantify the contact pressure on the anterior aspect of the knee during kneeling, and to determine the relationship between kneeling ability and contact pressure.

Material and Methods

The subjects included 26 volunteers and 60 patients who had undergone primary TKA for end-stage knee osteoarthritis. To measure the contact pressure and contact area, we used the I-SCAN. The I-SCAN is a pressure mapping device that employs a system of surface-pressure measurement sensors with a spatial resolution of 5.41 mm. The sensor used by the system for collecting interface pressure is 0.1 mm thick. Each participant was asked to face forward while kneeling for 10 seconds, at 90° knee flexion without using hand support. We measured the peak contact pressure and contact area as the participants knelt directly on the hard floor.

Results

In the post-TKA patient group, 22 patients were unable to kneel, 13 patients experienced extreme difficulty, 10 patients experienced moderate difficulty, 10 patients experienced little difficulty, and 5 patients could kneel easily. The peak contact pressure during kneeling was 1.33 $N/cm^2/kg$ in the volunteer group and 0.77 $N/cm^2/kg$ in the post-TKA patient group. The peak contact pressure was significantly lower in the patient group than in the volunteer group. The average total contact area during kneeling was 1066 mm^2 in the volunteer group and 1143 mm^2 in the post-TKA patient group. There was no significant difference between the groups. The percentage of load of the kneeling side during kneeling was 42.9% in the volunteer group and 33.2% in the post-TKA patient group. The load of the kneeling side was significantly lower in the patient group than in the volunteer group.

Discussion

We quantitatively measured the contact pressure on the anterior aspect of the knee during kneeling and found that the contact pressure was significantly lower in patients after TKA than in volunteers. We believe that, after TKA, patients might not be able to keep their weight on the operative leg during kneeling. As a result, the contact pressure was significantly lower in the patients. In fact, it was shown that the load of the kneeling

side was significantly lower in patients who had undergone TKA than that in volunteers.

Conclusions

This is the first study to perform quantitative measurements of contact pressure while kneeling. Although no differences were found between the contact areas of post-TKA patients and healthy individuals, while kneeling, the contact pressure and the load of the kneeling side/body weight of the post-TKA patients were significantly lower.

#5913

Analysis of a Custom Tibial Insert to Improve Functional Outcomes Following Total Knee Arthroplasty

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INTRODUCTION:
Postoperative functional limitations after Total Knee Arthroplasty (TKA) are caused, in part, by a mismatch between a patient's natural anatomy and conventional "off-the-shelf" implants. To address this, we propose a new concept combining off-the-shelf femur and tibia implants with custom polyethylene tibial inserts designed to account for a patient's unique anatomy. Our goal in this study was to use knee specific computational modeling to determine the neutral path of motion and laxity of an intact knee under axial compression and shear forces through full flexion and compare intact motion against the same knee implanted with a conventional off-the-shelf vs. a custom tibial insert.

METHODS:
3D models of a healthy knee joint were acquired from an open development repository funded by the National Institute of Biomedical Imagining and Bioengineering [1]. The knee model was virtually implanted with conventional (off-the-shelf) posterior cruciate retaining (CR) components including the femoral component, tibial tray, and a conventional insert. A custom CR tibial insert was designed taking into account native articular geometry and compatibility with placement of the off-the-shelf femoral/tibial tray. Bone, cartilage and implant models were imported into ANSYS Workbench. Ligament were calibrated using data from in-vitro experimental tests [1]. The following load conditions were applied to the femur: 20 N axial compression (neutral path), 20 N axial compression with 80 N anterior shear force, and 20 N axial compression with 80 N posterior shear force. Simultaneously for each loading condition, the knee was flexed from 0 - 120 degrees. A circular axis system was used to describe the motion of the femur relative to the tibia.

RESULTS:
For the intact case, neutral path was characterized by greater posterior femoral displacement on the lateral side than on the medial side, especially in early flexion (Fig.1). Neutral path of the custom insert was closer to intact condition than the conventional insert (Fig. 1). Overall AP laxity was similar between intact and implanted models except at 30 degrees where increased laxity occurred posteriorly for the implanted models, likely due to resection of the anterior cruciate ligament (ACL) as part of the TKA procedure. For intact and implanted models, AP laxity significantly decreased at the higher flexion angles (Fig. 2 and 3).

DISCUSSION:
Our findings indicate that motion with a custom tibial insert was closer to intact than the conventional design. Nonetheless, custom articular surface alone may not fully reproduce intact motion due to limitations such as resection of the ACL, and such custom inserts may benefit from guiding features such as a cam, post, or retention of the native ACL to more closely reproduce normal knee function. We did not simulate specific activities of daily living. Increasing the magnitudes of compression and shear forces would not change the neutral path of motion, although, a reduction in laxity would be expected.

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Figures

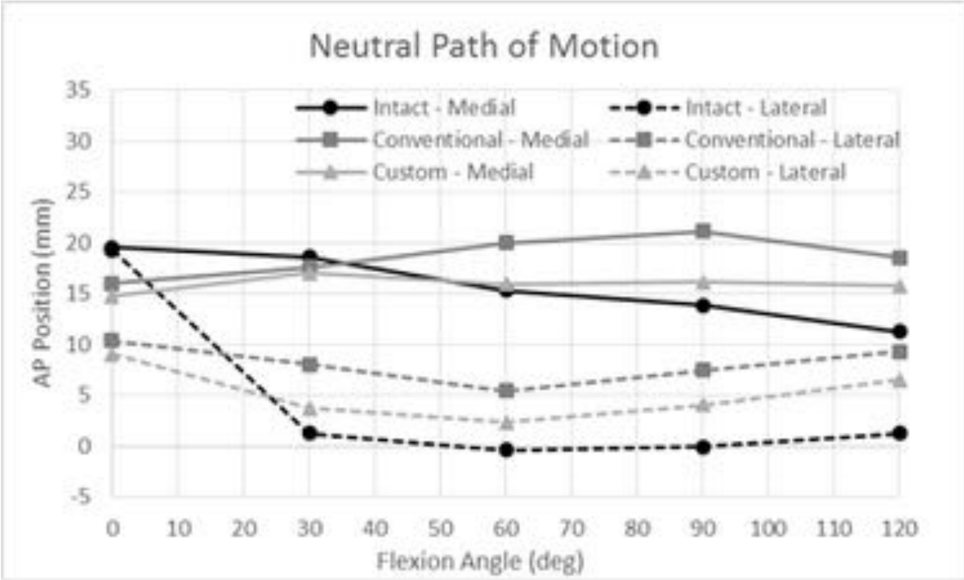

Fig. 1. Neutral path of motion for intact and implanted models under a compressive load between 0 – 120 degrees of flexion.

Figure 1

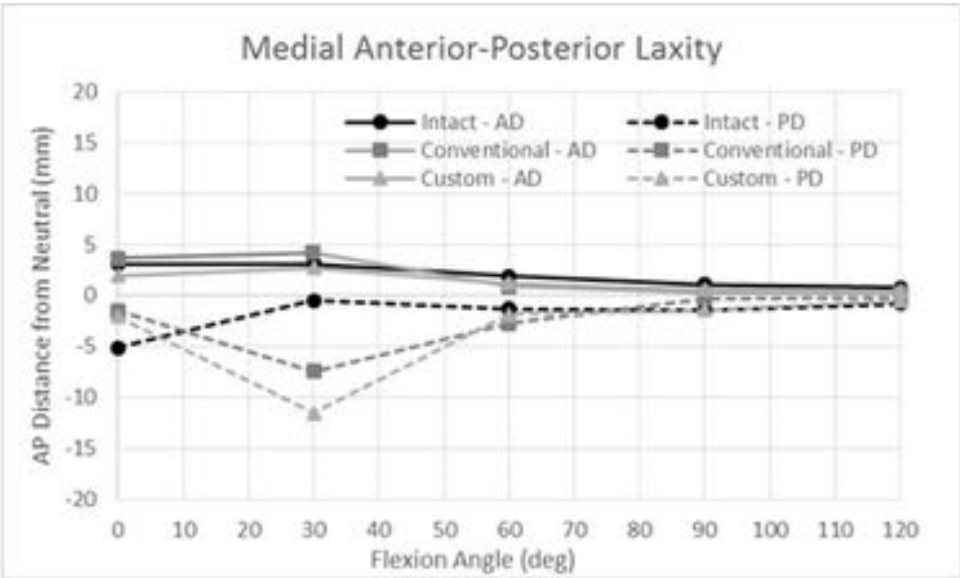

Fig. 2. Anterior-posterior laxity of the femoral medial side under axial compression. AP distances were taken relative to the neutral position. AD = anterior displacement, PD = posterior displacement

Figure 2

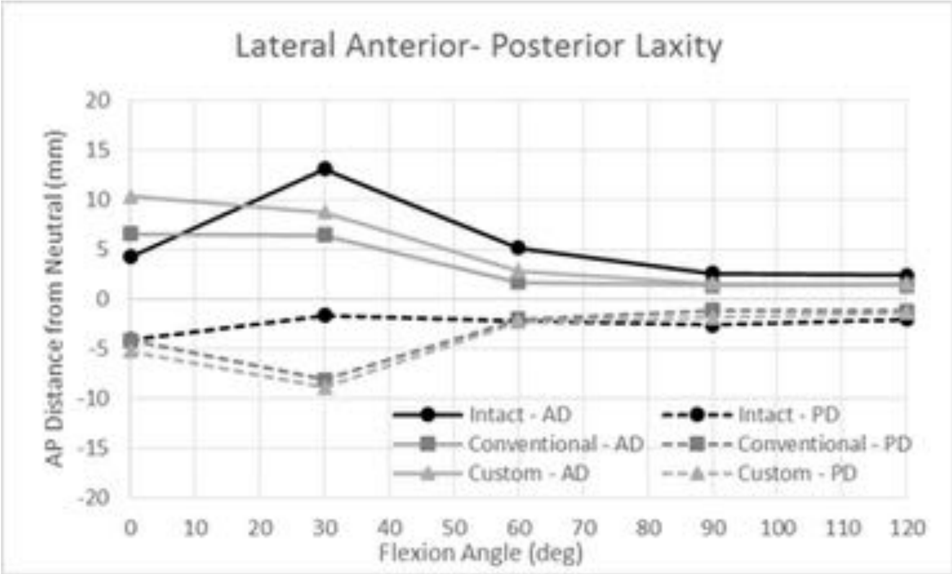

Fig. 3. Anterior-posterior laxity of the femoral lateral side under axial compression. AP distances were taken relative to the neutral position. AD = anterior displacement, PD = posterior displacement

Figure 3

#6062

Sagittal Stability of Medial Pivot Total Knee Arthoplasty Compared to Other Implant Designs

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Introduction

In total knee arthroplasty, the aim is to relieve pain and provide a stable, functional knee. Sagittal stability is crucial in enabling a patient to return to functional activities. Knee implants with a medial pivot (MP) design are thought to more accurately reproduce the mechanics of the native joint, and potentially confer greater antero-posterior stability through the range of flexion than some other implant designs.

Aim

This study aims to compare the sagittal stability of four different total knee arthroplasty implant designs.

Method

Comparison was made between four different implant designs: medial pivot (MP), cruciate retaining (CR), posterior stabilised (PS) and deep dish (DD). A cohort of 30 Medial Pivot (MP) knees were compared with matched patients from each of the other designs, 10 in each group. Patients were matched for age, body mass index and time to follow up.

Clinical examination was carried out by an orthopaedic surgeon blinded to implant type, and sagittal stability was tested using a KT1000 knee arthrometer, applying 67N of force at 30Ëš and 90Ëš.

Results

The MP knee was more stable than the CR knee at both 30º (mean movement: 1.37mm vs 2.48mm, p=0.037) and 90º (1.68mm vs 2.37mm, p=0.030).

The MP knee was more stable than the PS knee at 30º (0.98mm vs1.33mm, p=0.013). The MP knee also demonstrated less movement at 90 º (0.98mm vs 1.33mm), but this was not statistically significant (p=0.156).

The MP knee was more stable than the DD knee at 30 º (0.48mm vs 1.33mm, p=0.03) and 90 º (0.67mm vs 1.15mm, p=0.048).

Overall the medial pivot design was more stable than all non-medial pivot designs at 30 º (0.8mm vs1.66mm, p=0.003) and 90 º (1.1mm vs 1.61mm, p= 0.008).

Conclusion

Overall, the medial pivot design demonstrated significantly greater antero-posterior stability than all other design types included in this study. Correlation with patient reported outcome scales will allow insight into whether these statistically significant differences are also clinically significant.

#6191

Implant Geometry and Alignment Driven Variability in Post-TKA Kinematics

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Introduction

Kinematics post-TKA are complex; component alignment, component geometry and the patient specific musculoskeletal environment contribute towards the kinematic and kinetic outcomes of TKA. Tibial rotation in particular is largely uncontrolled during TKA and affects both tibiofemoral and patellofemoral kinematics. Given the complex nature of post-TKA kinematics, this study sought to characterize the contribution of tibial tray rotation to kinematic outcome variability across three separate knee geometries in a simulated framework.

Method

Five 50th percentile knees were selected from a database of planned TKAs produced as part of a pre-operative dynamic planning system. Virtual surgery was performed using Stryker (Kalamazoo, MI) Triathlon CR and PS and MatOrtho (Leatherhead, UK) SAIPH knee medially stabilised (MS) components. All components were initially planned in mechanical alignment, with the femoral component neutral to the surgical TEA. Each knee was simulated through a deep knee bend, and the kinematics extracted. The tibial tray rotational alignment was then rotated internally and externally by 5â° & 10â°.

The computational model simulates a patient specific deep knee bend and has been validated against a cadaveric Oxford Knee Rig. Preoperative CT imaging was obtained, landmarking to identify all patient specific axes and ligament attachment sites was performed by pairs of trained biomedical engineers. Ethics for this study is covered by Bellberry Human Research Ethics Committee application number 2012-03-710.

Results and Discussion

From the 360 Knee Systems database, 1847 knees were analysed, giving an average coronal alignment of 4.25â°±5.66â° varus. Five knees were selected with alignments between 4.1â° and 4.3â° varus. Kinematic outcomes were averaged over the 5 knees. The component geometries resulted in characteristically distinct kinematics, in which femoral rollback was most constrained by the PS components, whereas tibiofemoral axial rotation was most constrained in MS components. Patella lateral shift was comparable amongst all components in extension, medialising in flexion. Patella shift remained more lateral in MS components compared to PS and CR.

Average patella lateral shift, medial and lateral facet rollback separated by tibial tray rotation are shown for all component systems in Figure 1. Medial and lateral facet rollback in the PS and CR components are symmetrical and opposite, indicating that with tibial tray rotation, the tibiofemoral articulation point balances between component rotation and neutral alignment, reflecting the restoring force exerted by the simulated collateral ligaments. As such, with higher internal tibial rotation and subsequent lateralisation of the tubercle, patella lateral shift increases. MS medial and lateral facet rollback however are not symmetrical nor opposite, reflecting the chirality of the tibiofemoral articulation. With internal tibial tray rotation, relatively high lateral facet rollback is observed, lateralising the femoral component centre, giving the patella component a relatively more medial position.

Conclusions

Component geometry was found here to produce characteristically distinct tibiofemoral and patellofemoral kinematics. Medial stabilised components reported asymmetric kinematic changes, compared to either CR or PS components, in which a higher rate of change was observed for internal tray rotation, indicating that neutral or external rotation of medial stabilised components will result in more predictable kinematic outcomes.

Figures

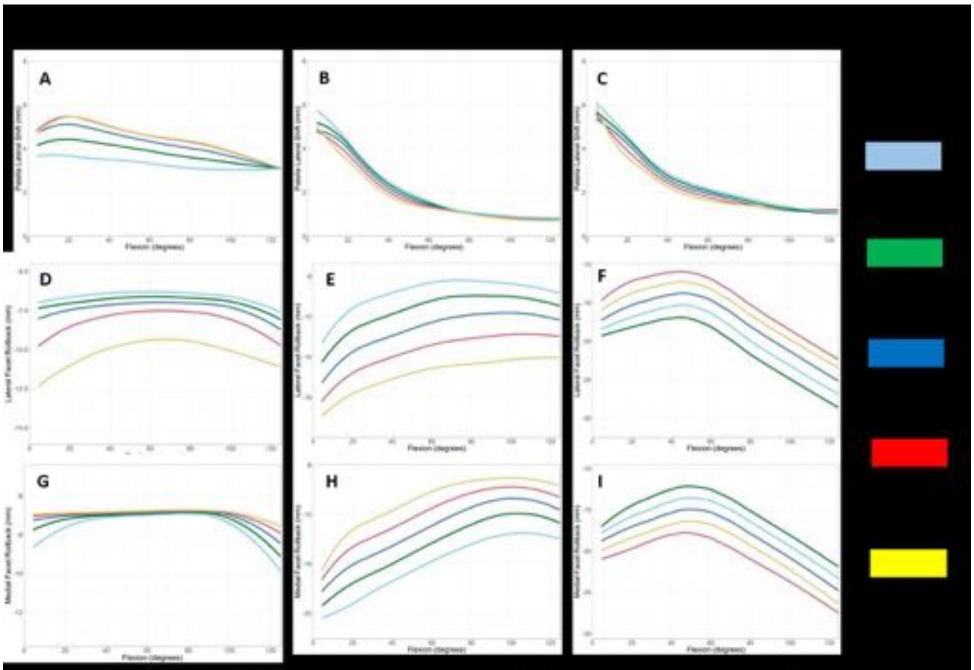

Figure 1 Average simulated medial facet rollback, lateral facet rollback and patella lateral shift for SAIPH (A,D,G) and Triathlon PS (B,E,H) and CR (C,F,I) components showing tibial rotation from 10° internal to 10° external.

Figure 1

#6194

The Native Tibiofemoral Kinematics in Bicruciate-Retaining Total Knee Arthroplasty

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Background: Total knee arthroplasty (TKA) is an effective surgical procedure to alleviate excruciating pain and correct dysfunction due to severe knee deformity.
The satisfaction rate with current TKA is 80%, While 20% of the patients report uncomfortable feeling during stair descending and deeply knee bending.

Preserving the ligaments might allow a restoration close to the natural function, although sacrifice of the ACL is common with the conventional TKA technique. The current bicruciate-retaining (BCR) TKA would be a way to go concerning this issue. This study aimed at evaluating the intraoperative kinematics and joint laxity on BCR TKA if the native function would be replicated and thus assessing the range of motion (ROM) at final followup.

Methods: BCR TKAs were performed in 22 knees (12 women, 10 men, average aged 67.2-year-old) with image-free navigation system (Kolibli^{TM}) under general anesthesia. The intraoperative kinematics was evaluated about flexion extension gap (FEG), anterior-posterior translation (APT, bi-condylar rollback) and axial rotation (AR, medial pivot) with passive motion. These kinematic patterns were assessed with the post-operative ROM.

Results: There was no paradoxical anterior translation in any cases. The implant kinematics was regulated to the medial pivot motion at early flexion phase and the bi-condylar rollback motion to full flexion angle. The mean flexion was changed from 132 degrees at preoperation to 126 degrees at followup, and the mean flexion contracture improved from 4 degrees to 1 degrees.

Conclusion: BCR TKA were preserved the nature kinematics including the medial pivot motion and rollback mechanism. Postoperative ROM was quite similar when the preoperative knee flexion was not restricted

#6058

Quantitative Assessment of Straight Leg Raising Test on Tibial Contact Loads During Total Knee Arthroplasty.

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Introduction: Instrumented load sensors have been used in soft tissue calibration and load distribution in the course of total knee arthroplasty for several years. A common criticism of the method has focused on the inert nature of the soft tissue envelope contractility under anesthesia. Furthermore, recent work has emphasized the important role of muscle action in stabilizing the knee and improving function and satisfaction. This study aims to demonstrate the quantitative changes in the load magnitude and relative distribution as patients raise their leg during a wake-up test under spinal anesthesia.

Methods: This study is an approved prospective pilot study of 25 patients who performed a volitional straight leg raising maneuver under verbal command at the conclusion of instrumentation and final cementing of a total knee arthroplasty. The spinal anesthetic formula was modified to allow return of motor function within an hour of the induction. The sensory block and sedation were not affected by this. Video capture of the event was made through a lateral perspective to capture the efficiency: height, knee flexion, duration and speed of the maneuver. The tibial load magnitude and relative compartmental distribution were recorded throughout as seen in Fig 1.

Results: There was found to be variability in the efficiency of the spinal anesthetic recipe. Smaller patients had residual motor block and either could not perform the task satisfactorily or at all. Of the 17 patients who had enough power, the relative increase in magnitude of tibial load force was in the range of 2.8 to 4.3, with an average of 3.4. The relative medial to lateral load distribution was preserved in 15 cases. There were no complications. No patient experienced any negative memory recall from the test.

Discussion: As intra-operative load sensors gain popularity in soft tissue calibration, it is important to determine if the relatively low passive forces measured at surgery predict (or represent) the forces that would be encountered in weight-bearing (the boundaries of their usefulness). Naturally, the impact of ground reacting forces cannot be tested under operative settings. This study however demonstrates that even without a wake-up test a well- balanced knee can be expected to have a predictable 3 to 4 fold increase in load across the joint under reasonable isometric muscular contraction, while preserving the medial-lateral load symmetry. The ability to preserve this compartmental load symmetry indicates that balanced load values obtained at surgery could be a predictor of clinical success.

Figures

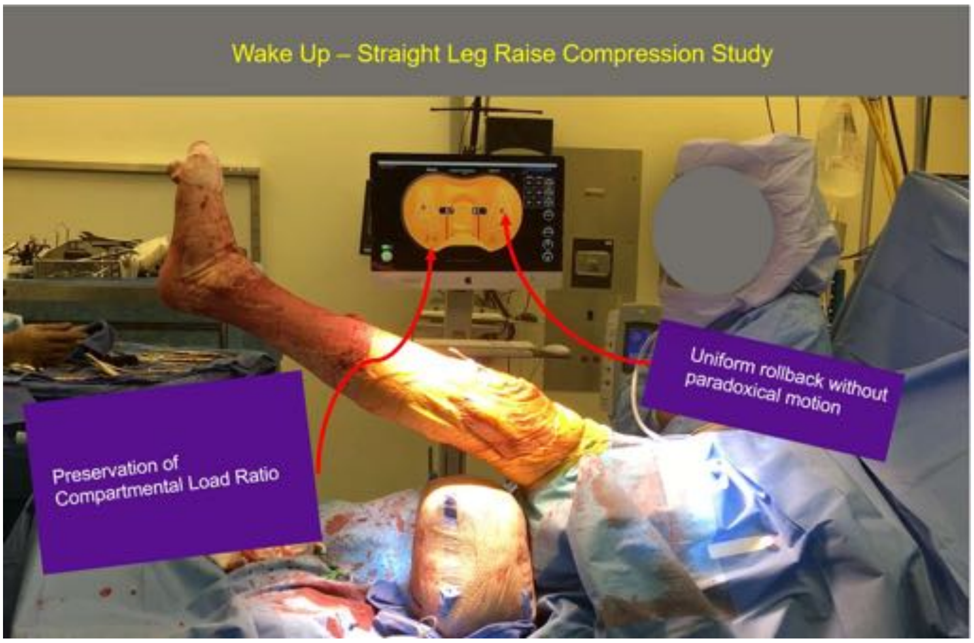
Wake Up – Straight Leg Raise Compression Study
Uniform rollback without paradoxical motion
Preservation of Compartmental Load Ratio

Figure 1

#5510

The Effect of Rotational Kinematics on Postoperative Range of Motion and Functional Activity Score After Posterior Stabilized Total Knee Arthroplasty.

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Background:

Patient satisfaction after total knee arthroplasty (TKA) has been lower than after a similar procedure, total hip arthroplasty. Poor subjective outcomes after TKA may be partially explained by abnormal kinematics patterns after TKA. The purpose of this study was to analyse rotational kinematics patterns in knees that had undergone posterior stabilized (PS)-TKA, and to clarify the relationships between rotational kinematics patterns and patient satisfaction, as well as between rotational kinematics patterns and knee function.

Materials & Methods:

A total of 49 osteoarthritis knees after primary PS-TKA (NexGen LPS-Flex fixed bearing knee system) were included in this study; deformed valgus, severe flexion contractures, and highly unstable knees were excluded. We used a computer navigation system and measured knee kinematics after each surgery was completed. A single investigator gently applied a manual range of motion from full extension to flexion. The angle of the internal rotation of the tibia was measured automatically at 0º, 30º, 45º, 60º, and 90º, along with maximum extension and flexion. We categorized the post-operative rotational kinematics patterns for individual cases, focusing on the initial knee flexion from 0–30º. Type A corresponded to an increased internal rotation angle of the tibia during the initial knee flexion (screw home-like movement). Type B corresponded to an increased external or an unchanged rotation angle of the tibia. We examined the range of motion (ROM) at 6 months after surgery and assessed the 2011 Knee Society Score (2011 KSS) at ≥1 year following surgery.

Statistical analysis. The difference between the two groups was compared using a Wilcoxon rank sum test. Analyses were performed with JMP statistical software v8.0 (SAS Institute). A p-value of <0.05 was regarded as significant.

Results:

The tibia exhibited an average of 5º of internal rotation at initial knee flexion. The type A kinematics pattern achieved a better ROM and functional activity score (2011 KSS) than the type B kinematics pattern.

Discussion:

Modern TKA implants have been designed to reproduce normal knee kinematics to achieve better patient satisfaction and knee function. However, few reports have described the relationship between the rotational kinematics patterns at initial knee flexion and patient satisfaction. In our study, the type A postoperative rotational kinematics pattern (screw home-like movement) had better ROM and functional activity score than the type B kinematics pattern. The movement toward the internal rotation of the tibia during initial knee flexion might be important in achieving better clinical results after PS-TKA.

#5543

Comparative Assessment of Gait in Total Knee Arthroplsty Patients Between Multi-Radius and Gradually Reducing Radius Femoral Component Designs During Sit-to-Stand and Stair Descent Movement

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Background: Previous studies demonstrated that an abrupt change in conformity occurs during flexion of knee joint after total knee arthroplasty (TKA) using the multi-radius (MR) femoral design implant. An abrupt change in conformity was shown to lead to instability such as paradoxical anterior sliding and anteroposterior movement. For this reason, a gradually reducing radius (GR) femoral design was introduced. Recent studies showed that the gradually reducing radius design helped to attenuate paradoxical anterior sliding and provide better contact area without point loading or edge loading. Rising from a chair, defined here as sit-to-stand (STS) task is a fundamental daily activity performed approximately 60 times per day by healthy adults. Stair decent is also another common daily ambulatory activity and considered more demanding than level walking. Therefore, the information comparing these tasks between MR and gradually GR knee designs should be addressed.

Objectives: The purpose of this study was to compare lower-limb biomechanics of TKA patients with MR versus gradually reducing radius GR knee design during sit-to-stand (STS) movement and stair descent.

Materials and Methods: Thirty-two knees were examined at one year after TKA. The groups consisted of subjects who had undergone total knee arthroplasty with a representative MR designed implant (n=15, B Braun-Aesculap Vega® Knee System) and a representative GR designed implant (n=17, Depuy Attune® Knee System). The kinematic and kinetic parameters of vertical ground reaction force, sagittal and coronal hip and knee range of motion (ROM), peak values of hip and knee adduction and flexion moments of hip and knee joints were evaluated during STS movement and stair descent. Patient-reported outcomes including Knee Society Score (KSS) and Knee Injury and Osteoarthritis Outcome Score (KOOS) were also evaluated. Independent t-test was done to compare the postoperative outcomes.

Results: During STS movement, STS duration was not significantly different between two groups. And, peak hip adduction moment of GR implant group was smaller than MR implant group ($p=0.014$) and peak knee flexion moment of GR implant group was greater than MR implant group ($p=0.011$). In the sagittal plane during stair descent, the knee was more flexed in the GR group than the MR group ($p=0.009$) and the flexion/extension ROM of the knee joint was significantly greater in the GR group than the MR group ($p=0.004$). In the coronal plane during stair descent, the maximal varus angle and the varus/valgus ROM of the knee joint were significantly smaller in the GR group than the MR group ($p<0.001$ and $p<0.001$). The adduction and flexion moments of hip and knee joints and Postoperative KSS and KOOS were not significantly different between two groups.

Conclusions: During STS movement, GR group showed more improved knee function with greater peak knee flexion moment, whereas MR group showed adaptative hip function with greater peak hip adduction moment to compensate knee joint after TKA. TKA performed with GR knee design implant also showed more flexed sagittal plane and more reduced coronal plane loading patterns of knee varus angle and excursion during stair descent when compared with MR knee design implant.

Figures

Figure 1. Femoral sagittal curvatures of a multi-radius total knee arthroplasty implant (left) and a gradually reducing radius implant (right).

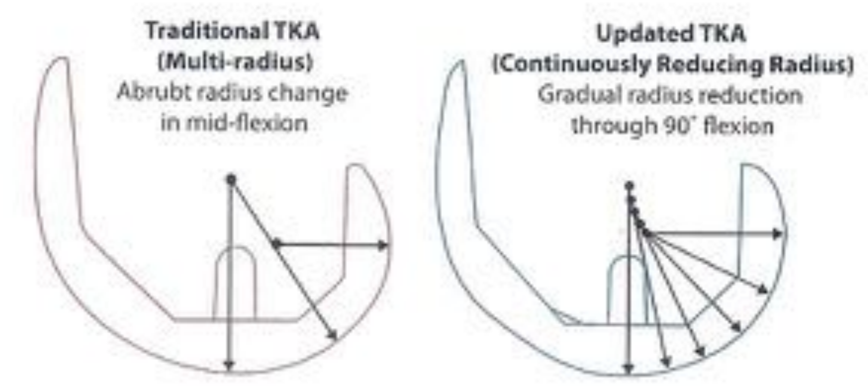

Figure 1

#6151

Fluoroscopic Study of Medial Pivot Knees During Stair Ascent and Descent

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Introduction

Joint kinematics following total knee replacement (TKR) is important as it affects joint loading, joint functionality, implant wear and ultimately patient comfort and satisfaction. It is believed that restoring the natural motion of the joint (such as the screw-home mechanism) with a medial pivot knee implant will improve clinical outcomes. Daily activities such as stair climbing and stair descent are among the most difficult tasks for these patients. This study analysed dynamic knee joint motion after implantation of a medial pivot knee implant using fluoroscopy during stair ascent and descent activity.

Methods

Ethics approval was granted by Macquarie University to undertake fluoroscopic testing. Four patients who had undergone a TKR were asked to participate in the study. All patients were operated by a single surgeon (JS) and were implanted with a medial pivot knee prosthesis (Sphere, Medacta International). Participants were tested at the 12 month post-operative time-point.

Participants were asked to step up or down a short stair-case at a comfortable self-selected speed. Fluroscopic images were taken using a flat panel Artis Zeego (Siemens Healthcare GmbH, Erlangen) angiography system during the dynamic activity. Images were processed using Joint Track Auto (Banks, University of Florida), whereby the specific femoral and tibial component CAD files were superimposed onto the fluoroscopic images, ensuring an optimised match to the outlined components. Joint kinematics were calculated using custom written code in Matlab 2017a.

Results

The average maximum flexion angle during stair ascent was 64° at the time when the foot had touched the step (Table 1). The average minimum flexion angle during this activity was 7.9°. On average, the tibia externally rotated relative to the femur by 3.6° as the knee extended. During stair descent (Table 2) the average flexion angle changed from a minimum of 4.3° of flexion to a maximum of 29.3° of flexion. The overall average change in internal rotation was only 0.1°.

Conclusion

The stair ascent activity showed the joint to undergo the natural screw-home mechanism motion; experiencing 4° of internal rotation over a 57° flexion angle range. The stair descent activity, however, did not exhibit the same level of internal-external rotation. This may be due to the other mechanisms such as motion adaptation of the patient when undertaking this activity, not related to the implant design.

Figures

Table 1. Joint motion during *Stair Ascent* activity

Average Maximum Flexion Angle	64.4 +/- 2.8
Average Internal Rotation (at Max Flexion)	4.9 +/- 5.8
Average Minimum Flexion Angle	7.9 +/- 7.4
Average Internal Rotation (at Minimum Flexion)	1.3 +/- 5.6
Average Flexion Range	56.5 +/-9.4
Average Change in Internal Rotation over Flexion Range	3.6 +/- 3.4

Figure 1

Table 2. Joint motion during *Stair Descent* activity

Average Maximum Flexion Angle	29.3 +/- 7.9
Average Internal Rotation (at Max Flexion)	4.7 +/- 0.5
Average Minimum Flexion Angle	4.3 +/- 5.6
Average Internal Rotation (at Minimum Flexion)	4.8 +/- 2.9
Average Flexion Range	25.0 +/-12.9
Average Change in Internal Rotation over Flexion Range	-0.1 +/- 2.5

Figure 2

#6095

Interface Tissue Engineering for Joint Replacement: Biomimetic Nanostructured Coatings, From Material Characterization to in Vitro Stem Cell Differentiation

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The possibility of covering the surface of orthopaedic implants according to biomimicry principles with nanostructured material to overcome the limitations of currently available coatings and improve the speed and quality of osseointegration at the bone/implant interface is a challenge in material science research. This study presents the results of biomimetic nanostructured coatings deposited from a natural bone-apatite source using a pulsed electronic deposition (PED) technique.

Coatings of biomimetic hydroxyapatite (BIOM) were obtained directly from targets of bone tissue, subjected to standard deproteinization procedure of cortical tibial cattle and compared to films deposited by sintered stoichiometric-hydroxyapatite objectives (HA). Deposition was performed at room temperature by PED. Half of the samples underwent heat treatment at 400°C for 1 hour (BIOM_400 and HA_400). Nanostructured coatings were characterized by morphological (SEM-EDS, AFM), structural (XRD, FT-IR) and mechanical (nanoindentation and microscratch) aspects immediately after deposition and after heat treatment. Biological tests were performed using human dental pulp stem cells (hDPSC), isolated from the dental pulp of routinely extracted dental patients, plated on samples (2500 cells/cm2) and cultured for 3 weeks, when the expression of typical Runx-2 osteogenic markers, osteopontin, Osx and Osteocalcin in hDPSC was evaluated.

Results showed that PED deposition allowed close transfer of target composition elements. The as-deposit coatings showed a low crystallinity, which was significantly increased after heat treatment, to resemble that of the initial bone target. As a result of heat treatment, mechanical properties have increased to values comparable to those of commercial HA plasma spray coatings.

In vitro biological tests have shown that BIOM_400 promotes the proliferation of hDPSCs to a greater extent than unhardened bone coating and HA references. Subsequent analysis, immunofluorescence and western blot revealed that typical osteogenic markers were expressed, indicating that BIOM_400 alone can effectively promote the osteogenic engagement of cells, even in the absence of an osteogenic medium.

In conclusion, the biomimetic apatite coatings were deposited by PED, which had a composition and structure very similar to that of natural apatite. After heat treatment at 400°C, the coatings showed satisfactory mechanical properties and were able to provide a microenvironment suitable for hDPSC adhesion and proliferation and osteogenic differentiation.

These results suggest that biomimetic nanostructured coatings obtained from a biogenic source can be an innovative platform for interface tissue engineering in orthopaedics, maxillofacials and dentistry.

#6174

Metal Ion Release From Conventional and Coated Femoral Components in Total Knee Arthroplasty (TKA)

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Objective: Metal sensitivity is an allergic reaction to metal ions released from implants. Few studies reported increased metal hypersensitivity rates in patients with TKA. The most common sensitizers causing metal allergy are nickel (Ni), cobalt (Co), chromium (Cr), and molybdenum (Mo). Research reveals that 20-25% of the well-performing total joint replacements and 60% of patients with poorly performing implants have metal hypersensitivity. One of the solutions to the reduction of metal ions is by coating the implant. Several studies typically compare the release of ions from a coated device to a non-coated device under static immersion testing and concluded that the coated devices are efficacious in acting as a barrier for metal ion release. However, the limitation of such studies is that it is unknown how these coated devices perform under kinematic conditions. There is a potential for a coating to breach in kinematic conditions since kinematic conditions are more aggressive than static test conditions. The objective of the current study is to compare the metal ions from a conventional and the coated femoral components when subjected to ISO 142423 wear testing and determine if coated femoral components still result in low metal ion release. The secondary objective is to determine if the coated device generate significantly lower metal ion when compared to conventional femoral component.

Methods: Testing was conducted on two groups (Group's A & B). Group A consisted of conventional femoral components made from ASTM F75 CoCrMo alloy while group B comprised of coated femoral components with TiNbN coating deposited on the ASTM F75 CoCrMo substrate. The tibial inserts for both groups were composed of GUR 1020 UHMWPE (non-cross linked) that was terminally sterilized by Eto process. Each group consisted of three bearing couples for wear test, and one bearing for the load or control soaks. Before testing, all the inserts soaked in the test lubricant for 48 hours. The soaked inserts were cleaned and weighed after removing from the test lubricant and tested in an AMTI knee wear simulator per ISO 14243-3 protocol. Post wear tests the serum samples were collected and analyzed for metal ions using ICP-MS.

Results & Discussion: Figure 1 shows the metal ion comparison between the conventional and coated femoral TKR components. There was a significant reduction in the release of Co, Cr, Mo and Ni ions from the coated devices when compared to the conventional femoral TKR components. Also, both group femoral components exhibited similar appearance with some scratches running in the anterior-posterior direction. The results from the study confirm that the coated devices yields significantly low ion release even under kinematic conditions and thus acts as an excellent barrier in the release of metal ions. The limitation of the current study is that the results cannot be generalized to other coated devices and is only applicable to the devices under review.

Figures

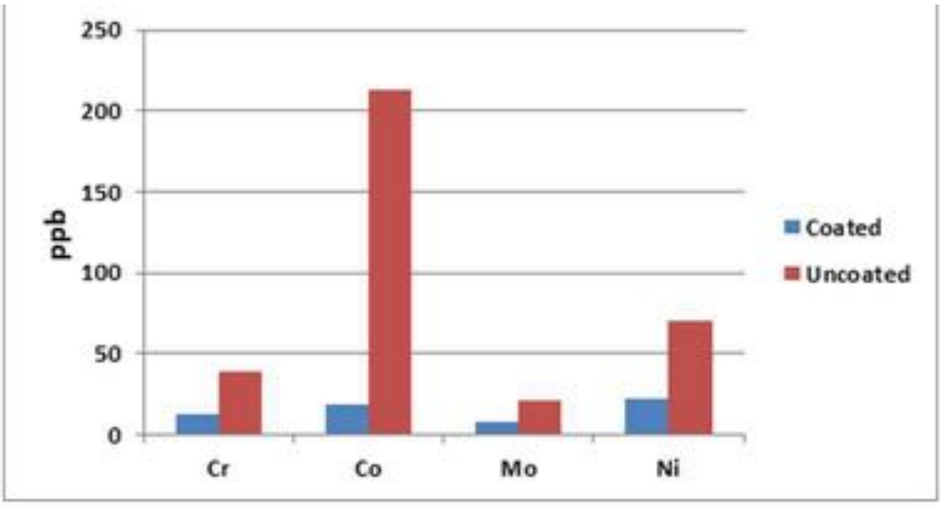

Figure 1: Metal Ion Results

Figure 1

#6009

Prosthetic Joint Infection and Aseptic Loosening - Could Liposomes Be the Solution?

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Objectives

Investigate the incorporation of an antibiotic in bone cement using liposomes (a drug delivery system) with the potential to promote osseointegration at the bone cement interface whilst maintaining antibiotic elution, anti-microbiological efficacy and cement mechanical properties.

Prosthetic joint infection and aseptic loosening are associated with significant morbidity.[1] Antibiotic loaded bone cement is commonly used and successfully reduces infection rates; however, there is increasing resistance to the commonly used gentamicin.[2,3]

Previous studies have shown gentamicin incorporated into bone cement using liposomes can maintain the cement's mechanical properties and improve antibiotic elution. [3]

The phospholipid phosphatidyl-l-serine has been postulated to encourage surface osteoblast attachment[4] and in a liposome could improve osseointegration, thereby reducing aseptic loosening.

Preliminary clinical isolate testing showed excellent antimicrobial action with amoxicillin therefore the study aims were to test amoxicillin incorporated into bone cement using liposomes containing phosphatidyl-l-serine in terms of antibiotic elution, microbiological profile and mechanical properties.

Methods

Amoxicillin was encapsulated within 100nm liposomes containing phosphatidyl-L-serine and added to PMMA bone cement (Palacos R (Heraeus Medical, Newbury, UK)).

Mechanical testing was performed according to Acrylic Cement standards (ISO BS 5833:2002).[5] Elution testing was carried out along with microbiological testing utilising clinical isolates.

Results

Liposomal encapsulated amoxicillin PMMA bone cement exceeded minimum ISO BS

5833:2002 standards, had better elution at 12.9% when compared with plain amoxicillin (p=0.036 at 48 hours) or commercial gentamicin cement (Palacos R+G, Heraeus Medical, Newbury, UK – previous studies showed 6% elution over the same time period).

Amoxicillin showed superior antimicrobial action when compared with gentamicin of the same concentration. However, liposomal encapsulated amoxicillin in solution and liposomal encapsulated amoxicillin in PMMA were both less effective than free amoxicillin in bacterial growth inhibition. The liposomal amoxicillin also seemed to decrease the cement setting time.

Conclusions

Phosphatidyl-l-serine containing liposomes maintained the cement's mechanical properties and seemed to have better antibiotic elution, however, had less effective antibacterial action than plain amoxicillin. This difference in antibacterial action requires further investigation along with investigation of osteoblast attachment to phosphatidyl-l-serine containing liposomes within cement.

Plain amoxicillin, for those not penicillin allergic, seems to be a credible alternative to gentamicin for incorporation in PMMA bone cement. It has shown superior antibacterial action, which may improve infection rates, whilst maintaining the cement's mechanical properties.

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#5808

A New Polymeric Dicalcium Phosphate (P-DCPD) Cement for Load-Bearing Bone Defects

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Purpose: Bone loss due to injuries suffered in wars and gunshot wounds remains a major clinical and socioeconomic problem. Many efforts have been made to provide new technologies for the treatment of large and load-bearing bone defects. Commercially existing calcium phosphate cements (CPCs) often lead to long-term graft failure due to weak mechanical strength, burst drug release and poor washout resistance. Calcium polyphosphate (CPP) represents a promising bone substitute because of its biocompatibility, mechanical strength, and stimulation of bone healing. CPP has shown promise as a drug delivery matrix following a unique gelling protocol. In this study, we described new injectable polymeric dicalcium phosphate cement cements (P-DCPD). We found that P-DCPD is mechanical strong for load bearing bone defects and capable of sustained antibiotics release.

Methods: P-DCPD was prepared by the setting reaction of mixing CPP gel with tetracalcium phosphate (TTCP). The physiochemical properties of P-DCPD was measured by fourier transformed infrared (FTIR) and X-ray diffractometry (XRD). The cement setting mechanisms were investigated by atomic force microscopy (AFM) and Raman spectroscopy. The handling properties of P-DCPD (setting time, setting temperature, injectability, mechanical strength, viscosity and washout resistance) were measured.

Results: First, we compared the handling properties of P-DCPD with commercial Hydroset cements (Stryker) (Table). Three steps of setting reactions (dissolution, diffusion and crystal growth) of P-DCPD were confirmed by impedance measurement. P-DCPD is superior to existing CPCs including, but not limited to, a constant viscosity, controllable setting, injectability and sustained drug release. An excellent washout resistance of P-DCPD was observed. This might be due to its high viscosity, short setting time (5-8 min) and the microstructure of entangled polyphosphate chains. A zero-order release of albumin from P-DCPD more than 4 months was observed. This might be due to the ionic interaction between albumin and the polyphosphate chains.

Conclusions: We described a “game-change” technology to prepare P-DCPD. In contrast to the classic CPC formula (reaction of monomeric acid calcium source with alkali calcium source), we used CPP as polymeric acidic calcium source. The in vitro setting mechanisms have been extensively investigated in the PI’s lab using XRD, FTIR, solid NMR and Raman Spectroscopy. P-DCPD is superior to existing CPCs including, but not limited to, a constant viscosity, controllable setting, injectability and sustained drug release.

Military trauma associated with orthopaedic injury accounts for approximately 65% of total casualties. Battlefield care of large bone defects and chronic bone defects represent a difficult and, as yet, unsolved clinical challenge. Despite substantial advances in the availability of bone graft substitute materials and continuous development of new bone regeneration technologies, these bone defects often fail to heal completely. P-DCPD, as developed in PI’s lab, is expected to meet these unmet clinical needs.

Figures

Parameters	P-DCPD	Hydroset
Compressive strength（Mpa）	65-70	5-15
Tensile strength（Mpa）	28-35	8-10
Setting time（min）	5-8	5-8
Washout resistance（%）	>99.5%	<40%
Viscosity（Pa S）	~100000	No
Drug release (weeks)	>16	<1

Figure 1

Characterization of Osteoconductive Si-Y-O-N Film Present at Annealed Silicon Nitride Surface

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Introduction: The osteogenic capability of any biomaterial is governed by a number of critical surface properties such as surface energy, surface potential, and topography. Prior work suggested that the Si-Y-O-N phase(s) present in the form of a thin (<150 nm), interrupted film at the surface of an annealed silicon nitride bioceramic may be responsible for an observed upregulation of osteoblastic activity due to passive surface properties and dissolution of chemical species. In this study high-resolution analytical electron microscopy was utilized to identify the Si-Y-O-N phase present on the annealed silicon nitride surface, and dissolution studies were employed to elucidate mechanisms of the material's favorable cell interactions.

Materials and Methods: Si_3N_4 discs (Æ12.7 x 1 mm) containing Y_2O_3 and Al_2O_3 sintering aids were processed using conventional techniques and subsequently subjected to annealing in a nitrogen atmosphere. Pre-cultured SaOS-2 osteosarcoma cells at a concentration of 5 x 10^5 cells/ml were seeded onto sterile polished nitrogen-annealed Si_3N_4 discs in an osteogenic medium consisting of DMEM supplemented with about 50 µg/mL ascorbic acid, 10 mM β-glycerol phosphate, 100 mM hydrocortisone, and 10% fetal bovine calf serum. The samples were incubated for up to 7 days at 37°C with two medium replenishments. Transmission electron microscopy (TEM) images were acquired from focused ion beam (FIB)-prepared samples using a Hitachi HF-3300 TEM (300 kV). Scanning transmission electron microscopy (STEM) images were recorded using a Nion UltraSTEM 100 (60 kV). STEM high-angle annular dark-field (HAADF) imaging and energy dispersive X-ray spectroscopy (EDS) analyses were performed on a JEOL JEM2200FS (200 kV) equipped with a third-order CEOS aberration corrector and a Bruker XFlash silicon drift detector.

Results: A cross-section of the of the Si_3N_4/extracellular polymer (ECP) interface is illustrated in Fig. 1(a)~(b) as a high-angle annular dark field (HAADF) STEM image (a) with and EDS map overlay (b) highlighting locations of Ca, Y, and Si. The underlying Si_3N_4 microstructure is covered by a yttrium-rich intergranular phase (IGP) film. Deposition of cell-derived hydroxyapatite (HAp) occurred directly onto this IGP film. In Fig. 2, a bright field TEM image (electron diffraction pattern inset) shows the interface between the partially-crystalline HAp and the Y-Si-O-N phase, identified as monoclinic yttrium disilicate (*i.e.*, m-$Y_2Si_2O_7$) with a 2 atomic% N impurity, at teh atomic scale. Although rapid electron damage of the mineralized ECP was observed, EDS analyses suggested a Ca/P ratio of ~1.43, along with the incorporation of Si.

Conclusions: The osteogenic Si-Y-O-N phase was successfully identified as a minority concentration of of Si_3N_4 dissolved into a m-$Y_2Si_2O_7$ matrix. Evidence of the release of $(SiO_4)^{4-}$ tetrahedra from this phase into the local biological microenvironment and their incorporation into the cell-derived HAp layer was also observed. Identification of this phase paves the way for ongoing work to understand and optimize this novel biomaterial.

Figures

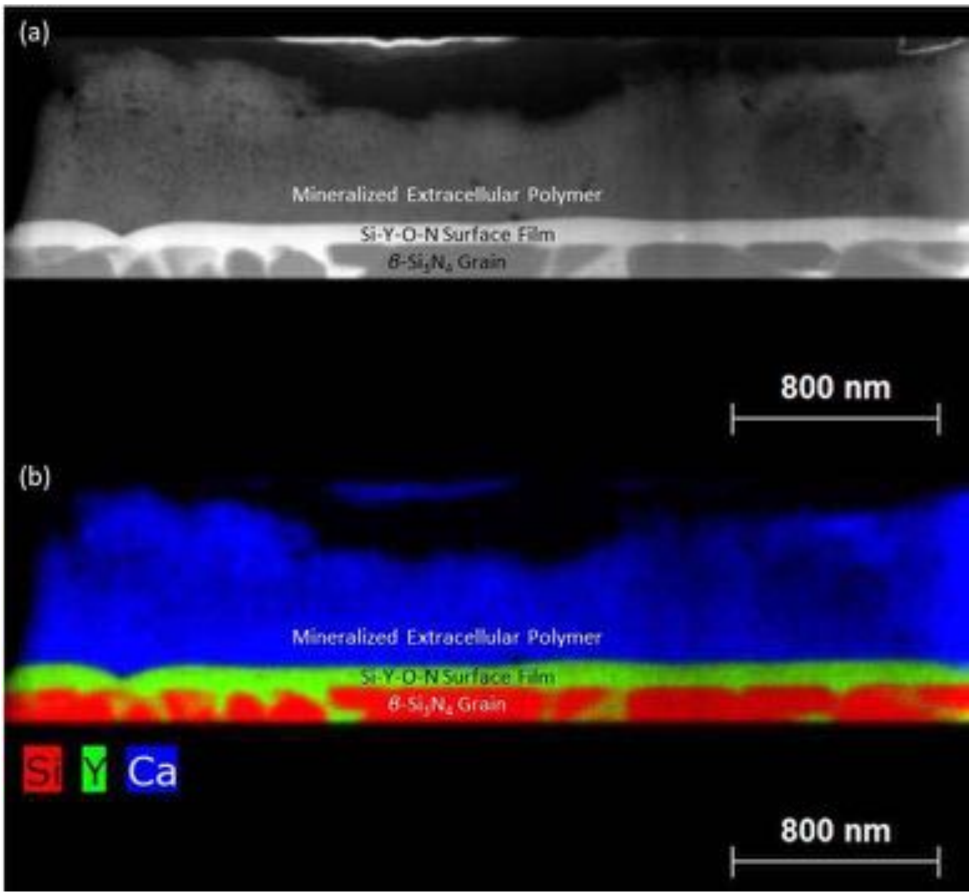

Figure 1

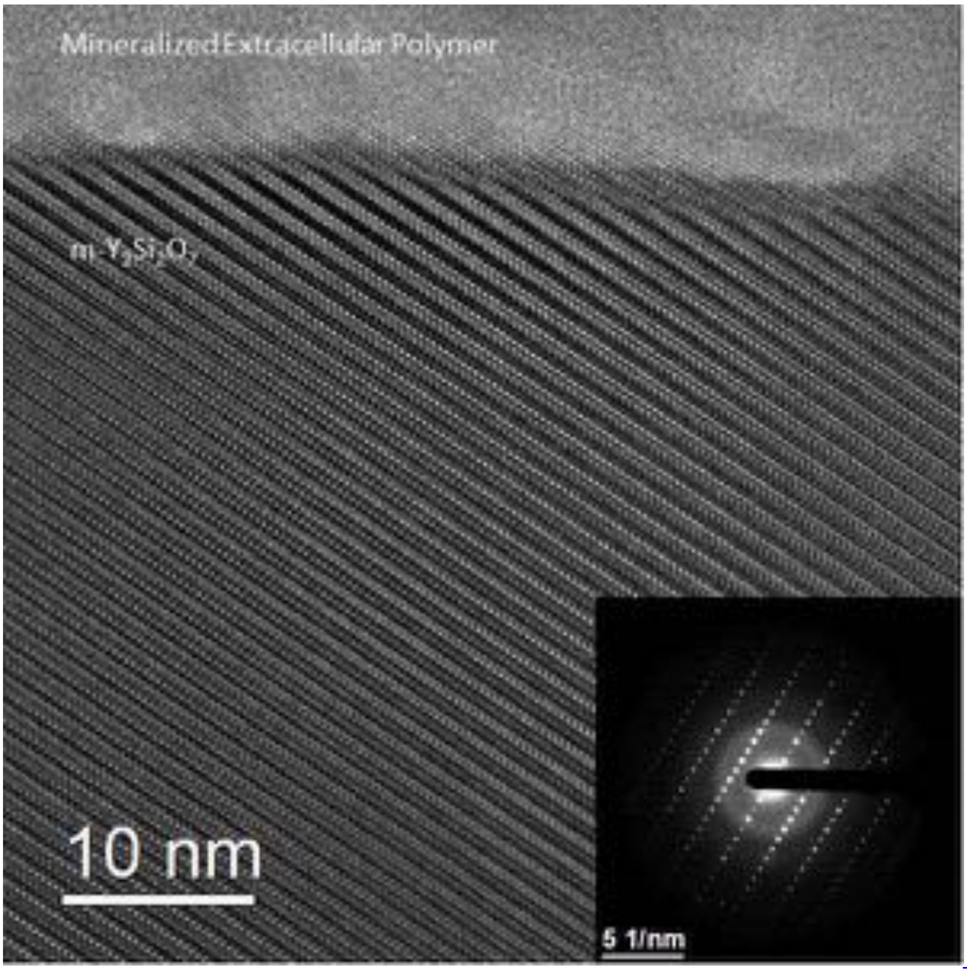

Figure 2

#5917

An All-Polymer Total Knee Replacement

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Introduction

PEEK-OPTIMA™ is currently being investigated as an alternative to cobalt chrome in the femoral component of a total knee replacement, coupled with an all polyethylene tibial component (Figure 1) and polyethylene patella button. Prior to *in vivo* clinical trials it is essential to predict functional performance of new material combinations *in vitro*. Hence a pre-clinical assessment of the wear of this novel material couple has been performed through a series of fundamental simple geometry pin-on-plate studies through to full geometry tibiofemoral and patellofemoral joint wear simulation, under a range of conditions.

Methods

The influence of lubricant temperature (standard rig running and elevated temperature (~36°C)) on the wear of a UHMWPE-on-PEEK OPTIMA™ bearing couple using different lubricant protein concentrations (0, 2, 5, 25 and 90% bovine serum) was investigated using a 6 station multi-directional pin-on-plate wear simulator. The studies were repeated for UHMWPE-on-cobalt chrome in order to compare relationships.

Experimental wear simulation of the tibiofemoral and patellofemoral joints was carried out using a 6-station Pro-sim knee simulator with kinematic input profiles to replicate a walking gait cycle. The all-polymer knee replacement (collaboration partners Maxx Orthopedics Inc., Plymouth Meeting, PA, USA and Invibio Knee Ltd, Thornton-Cleveleys, UK) was investigated in parallel with a conventional metal-on-polyethylene implant (MAXX Orthopaedics Inc.) of similar initial surface topography and geometry. EO sterilised UHMWPE components were used with minimum n=3 and 5 million cycles of wear simulation for each study. 25% bovine serum was used as a lubricant and the wear of UHMWPE was assessed gravimetrically. Statistical analysis of the wear rates of the different material combinations was performed using Students t-test ($p<0.05$).

Results

The pin-on-plate studies showed that in low lubricant protein concentrations (≤ 5%) there was no influence of temperature on the wear factors of UHMWPE-on-PEEK. With 25% bovine serum, the wear factor of UHMWPE-on-PEEK reduced by half at elevated temperature. When tested in high protein concentration (90% serum), there was no influence of temperature on the wear factor of UHMWPE-on-PEEK. These temperature dependencies were not the same for UHMWPE-on-cobalt chrome.

The wear of UHMWPE in both the tibiofemoral and patellofemoral joints was low, <5mm^3/MC and <1mm^3/MC respectively. There was no significant difference in the wear performance of the UHMWPE components against the different femoral component materials, $p=0.27$ and $p=0.38$ for the tibiofemoral and patellofemoral joints respectively. Scratching was observed on the surface of the PEEK femoral components however, this did not influence the wear rate which remained linear over the duration of the study.

Conclusion

The pin-on-plate studies showed the importance of the selection of appropriate test conditions when investigating the wear of different materials, in order to minimise test artefacts such as polymer transfer, and protein precipitation and deposition.

Experimental wear simulation of both tibiofemoral and patellofemoral joints showed an equivalent rate of wear of UHMWPE against PEEK-OPTIMA™ and cobalt chrome femoral components.

Before the product enters in vivo clinical trials, these studies show PEEK-OPTIMA™ to have promise as an alternative to cobalt chrome in the femoral component of total knee replacements.

Figures

Figure 1 All Polymer Knee

Figure 1

Metal-on-Polycarbonate-Urethane Total Hip Arthroplasty: A Prospective Study at 5 Years Follow-Up

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Objectives

Total hip arthroplasty (THA) is one of the most successful surgical procedures; several bearing technologies have been utilized, however none of these is optimal. Metal on polycarbonate-urethane (PCU) is a new bearing technology with several potential advantages: PCU is a hydrophilic soft pliable implant quite similar in elasticity to human cartilage, offers biostability, high resistance to hydrolysis, oxidation, and calcification, no biodegradation, low wear rate and high corrosion resistance and can be coupled with large metal heads (Tribofit Hip System, THS).

The aim of this prospective study was to report the survivorship and the clinical and radiographic outcomes and the metal ions dosage of a group of patients operated with metal on PCU arthroplasty featuring large metal diameter heads, at 5 years from surgery.

Study Design & Methods

The patients have been contacted by phone calls and invited to return to our centre for clinical (Oxford Hip Score, OHS, and Harris Hip Score, HHS), radiographic and metal ion levels evaluation. 68 consecutive patients treated with the THS were included. All the patients were operated with uncemented stems.

Results

The survival rate is 100% and no major complications were seen. The average preoperative OHS was 17 (6-34), at follow-up it was 44 (40-48). The average preoperative HHS was 48 (12-76), at follow-up it was 93 (84-100). On the x rays taken at follow-up, no signs of periprosthetic bone rarefaction and/or osteolysis were seen. No signs of PCU liner wear were visible. At follow up mean Co serum level was 0.52 ng/mL (<0.1-2.5, sd 0.5), mean Cr level was 0.27 ng/mL (0.1-2.2, sd 0.2). In this prospective study at a mean follow up of 5 years, all implants were well functioning, with no radiological signs of loosening and normal serum levels of cobalt and chrome. Although large diameter metal heads and metal sleeve were used no trunnionosis occurred.

Conclusions

We believe that these positive outcomes are due the positive biomechanical characteristics of PCU. These results need to be confirmed at a longer follow up and in a more active younger patient population.

#6153

The Design and in-Vivo Testing of a Locally Stiffness Matched Porous Scaffold

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Orthopedic implants have traditionally been solid pieces of metal that are orders of magnitude stiffer than natural bone. Whilst great success has been seen with these devices opportunities exist for improvements in implant fixation and reducing stress shielding. Incorporating additively manufactured porous features, allows implant designers to tailor the stiffness of implants to the bone being replaced. It may then be possible to create implants that produce strain fields that accelerate bone formation. The aim of this study is to explore trabecular bone in-growth in response to varying strain gradients in-vivo. It is predicted that matching the stiffness (strain gradient) of the trabecular bone being replaced will result in greater bone in-growth when compared to an industry-standard stiffer porous scaffold.

Trabecular bone cores from 10 ovine hind-femurs were CT scanned to extract bone density values, then compression tested to extract apparent modulus (E) values. Consequently, a stiffness-density relationship for ovine bone was generated. Two Ø16mm x 15mm implants were designed, one of a stiffness similar to typcial industry-standard porous implants (6 GPa) and one which was locally stiffness matched to the bone it would be replacing. Implants were additively manufactured from commercially pure titanium powder. The animal study was performed in 6 skeletally mature ewes (UK home office, license no. 70/8247). Each hind femur contained either a stiffness matched implant or a conventionally ‘stiff’ porous implant implanted in the medial femoral condyle (Figure 1). Sheep were euthanised at 6 weeks. Specimens were retrieved and assessed by µCT, histology and fluorescent microscopy.

The modulus of ovine bone varied from 0.1 – 6 GPa depending on its location in the distal femur. A relationship between bone stiffness and CT density was established and used to generate a locally stiffness matched implant. For the stiffness matched implant, there was intimate bone ingrowth around the perimeter of the implant with an average of 14.3±3.2% bone ingrowth by volume (Figure 2). The smaller strut diameters generated a high surface area in contact with the bone and fluorescence imaging indicated a high level of osteoblast activity in these areas and no fibrous encapsulation was found. In areas of bone ingrowth, histology revealed typical patterns for woven and lamellar bone at the perimeter and within the implant (Figure 3). For the high stiffness implant, a bone ingrowth volume of 6.3±2.2% was calculated. There was less penetration of bone into the volume of the implant, and histology identified scar tissue forming within the implant where there would have been little strain (Figure 2). Fluorescence indicated reduced osteoblast activity both around the perimeter and within the stiff implant compared to the stiffness matched implant.

The most important finding of this study was that a porous AM material could tailor a strain gradient within an implant that accelerated bone formation in load-bearing environments. It also appears that bone regeneration within a scaffold is inversely proportional to scaffold stiffness. The formation of new bone observed in the stiffness matched implants mimics the process and structure of new natural bone formation.

Figures

Figure 1

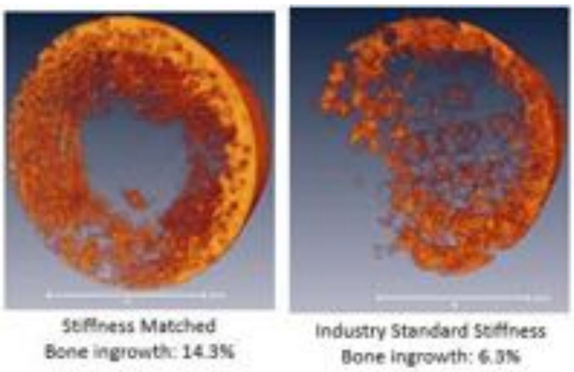

Figure 2

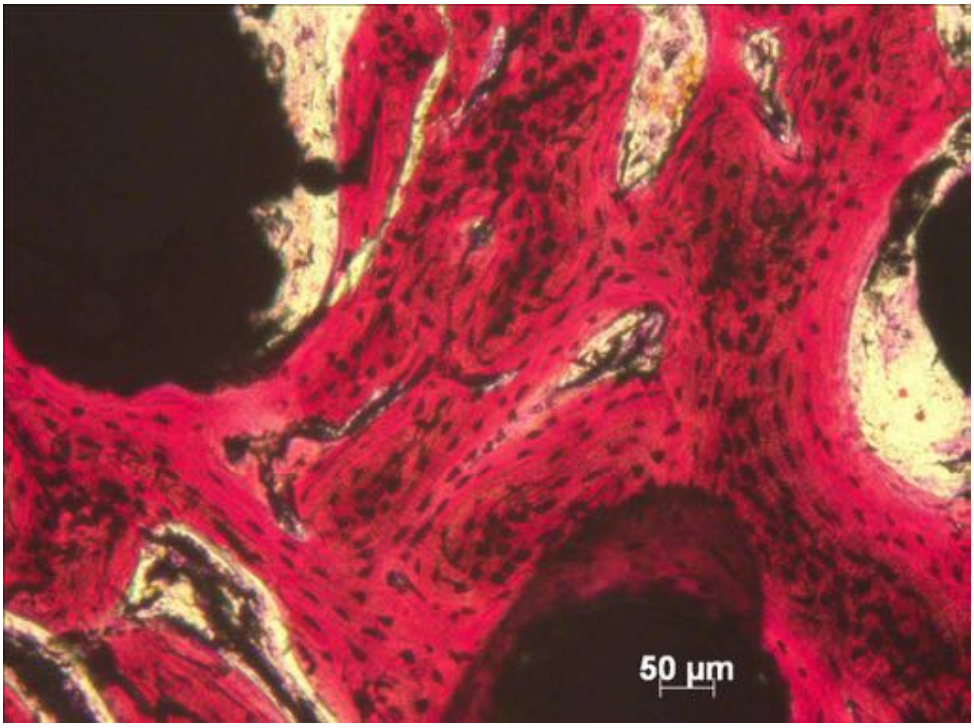

Figure 3

Intra- and Post-Operative Complications in Hip Hemiarthroplasty Using Conjoined Tendon Preserving Posterior Approach

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Introduction

The hip hemiarthroplasty in posterior approach is a common surgical procedure at the femoral neck fractures in the elderly patients. However, the postoperative hip precautions to avoid the risk of dislocations are impeditive for early recovery after surgery. We used MIS posterior approach lately known as conjoined tendon preserving posterior (CPP) approach, considering its enhancement of joint stability, and examined the intraoperative and postoperative complications, retrospectively.

Methods

We performed hip hemiarthroplasty using CPP approach in 30 patients, and hip hemiarthroplasty using conventional posterior approach in 30 patients, and both group using lateral position with the conventional posterior skin incision. The conjoined tendon (periformis, obturator internus, and superior/inferior gemellus tendon) was preserved and the obturator externus tendon was incised in CPP approach without any hip precautions postoperatively. The conjoined tendon was incised in conventional approach using hip abduction pillow postoperatively.

Results

There was no difference between CPP approach group and conventional approach group in the mean age of patients (81.8 years, and 80.3 years, respectively), and in the mean operative time (68.8 minutes, and 64.9 minutes, respectively). In 4 cases of CPP approach, the avulsion fracture at femoral attachment of the conjoined tendon occured during hip reduction manoeuvres. No dislocations occured in both groups in the follow-up period (2 years).

Discussion

Lately, the number of hip surgery in muscle sparing approach is increasing. However, in general, MIS approach induces the intraoperative complications, and requires the skillful procedure. The hip reduction manoeuvres would be more difficult in the CPP approach, than in conventional posterior approach, because the preserved conjoined tendon would inhibit hip reduction, considering those avulsion fractures of the femoral attachment. Nevertheless, CPP approach did not require no extended time compared to conventional approach, and no postoperative hip precautions. Due to these results, CPP approach could be a good MIS procedure including early recovery after surgery based on the enhancement of joint stability, excluding the difficulties in hip reduction manoeuvres. We could not show the difference in dislocation rate between two groups, because of small numbers. We are planning to increase the number of patients in the future study.

Preventing Neurologic Injury During Direct Anterior Total Hip Arthroplasty (THA) Using the Hana Table: A Novel Technique Incorporating Neuromonitoring During THA

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Introduction: The rate of total hip arthroplasty (THA) surgery continues to dramatically rise in the United States, with over 300,000 procedures performed in 2010. Although a relatively safe procedure, THA is not without complications. These complications include acetabular fracture, heterotopic ossification, implant failure, and nerve palsy to name a few. The rates of neurologic injury for a primary THA are reported as 0.7-3.5%. These rates increase to 7.6% for revision THA. The direct anterior total hip arthroplasty (DATHA) is gaining popularity amongst orthopedic surgeons. Many of these surgeons elect to use the Hana® table during this procedure for optimal positioning capability. Although intraoperative mobility and positioning of the hip joint during DATHA improves operative access, select positions of the limb put certain neurologic structures at risk. The most commonly reported neurologic injuries in this regard are to the sciatic and femoral nerves. To our knowledge, the use of neuromonitoring during DATHA, especially those using the Hana® table, has not been described in the literature.

Methods: The patient was a 60-year-old male with long standing osteoarthritis of the right hip and prior left THA. Somatosensory evoked potential (SSEP) leads were placed bilaterally into the hand (ulnar nerve) as well as the popliteal fossae (posterior tibial nerve). Unilateral electromyography leads were placed into the vastus medialis obliquus, biceps femoris, gastrocnemius, tibialis anterior, and abductor hallucis of the operative limb (Fig. 1). Once the patient was sterilely draped, a direct anterior Smith-Peterson approach to the hip was used.

Results: After the patient completed standard pre-operative protocol, neuromonitoring leads were placed as described above. There were no complications, neuromonitoring remained stable from baseline, and the patient tolerated the procedure well. Moreover, the senior author routinely uses a prophylactic cable around the calcar, particularly in patients with osteoporotic bone, as was the case with this patient. The patient's post-operative course has been without complications as well.

Conclusion: There are a few studies that have examined the pressure changes around the femoral nerve during a DATHA and found that the nerve was at most danger with misplacement of a retractor near the anterior lip of the acetabulum. Furthermore, the popularity of DATHA and the Hana® table make neuromonitoring more amenable for use since the whole limb does not need to be sterilely prepped as with other approaches to the hip. The reported rates of neurologic injury during any THA along with those developed from passage of prophylactic cerclage cables and the goals of reducing surgical complications make this novel technique intriguing. It allows the surgeon yet another safe and effective tool to decrease the likelihood of neurologic injury during DATHA.

#6159

Repeated Dislocation in Very Acute Phase After a Total Hip Arthroplasty; a Case With Possible Factitious Disorder

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Factitious disorder was previously called “Munchausen syndrome” and classified as a subtype of somatoform disorder in recent DSM-V. Literature reports about factitious disorder related to orthopedic area is few; however, hidden patient population may exist. The purpose of this paper is to present a case of a patient with a suspicion of factitious disorder who underwent a total hip arthroplasty then got her hip dislocated multiple times within one month after the surgery. A 70-year-old female presented with bilateral hip pain, weakness of both legs and neck to back pain. She could walk, but had used wheelchair outside her house for long time. She had wanted to come to the university hospital and visited multiple departments almost every day with a variety of complaint. Her past history includes depression, continuous temporal head pain after a traffic accident, accidental swallowing of plastic package of medicine and surgeries for osteoarthritis (OA) of both thumb. Those surgeries could not improve her pain and activity of daily life (ADL), but she deserved another surgery for back, neck and hips. Regarding to imaging studies, X-ray showed a mild OA of the hip, and MRI showed mild inflammation and cyst formation on the surface of right femoral neck. A surgeon wanted to help and improve her quality of life and ADL, after the consideration, she underwent a total arthroplasty of right hip. Physical therapy was started from day after the surgery, but she couldn’t acquire the posture to prevent dislocation well. The first episode of dislocation happened 9 day after the surgery and it was manipulated immediately. She wore an elastic hip orthosis after the incident, but her hip repeatedly dislocated in postoperative day 17, 26 and 38 (one day before planned discharge). As a result, her ADL was same before the surgery and complained more pain around operated hip. She was always hoping to get special attention from medical team. The discrepancy between her image studies and complaints, her past history and the short term result can suggest factitious disorder as a differential diagnosis. We should be careful about a hidden possibility of factitious disorder before undergo any surgeries in order to avoid unnecessary medical expenses, invasion and bitter results.

#5916

Qualitative and Quantitative Comparisons Between Acromegalic and Non-Acromegalic Patients With Direct Anterior Approach THA.

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Background

Acromegaly, which stems from high level of serum growth hormone secreted by a benign tumour in anterior pituitary grand, is likely to cause severe peripheral joint pains due to hypertrophic changes in such joints. Recently, the life expectancy of such patients has been improved and more patients with acromegaly have undergone joint surgeries to mitigate joint pain and malfunctions. However, little is known about to what extent surgical procedures can improve the joint functions of acromegalic patients compared to non-acromegalic cases.

Methods

First, we qualitatively analysed prognosis of total hip arthroplasty (THA) of acromegalic patients by investigating 11 cases in which direct anterior approach (DAA) THAs were performed to 8 acromegalic patients in our hospital between 2012 and 2015.

Second, we quantitatively compared the functional prognosis of the 11 cases with that of 107 non-acromegalic cases. Technically, to control the difference in age, sex, height, and weight between the two patient groups, we first identified a model that could predict 3month-/6month-/12month-functional prognosis in the control cases. We estimated differences in functional outcomes between the two groups by calculating how accurately the control-case-based model could predict the prognosis of the acromegalic cases.

Results

In the qualitative analysis, we found that compared to the control, the most acromegalic cases had atypically advanced degenerative arthritises with osteophytes and enthesophytes proliferations. In addition, some cases showed other signs, such as flattering of femoral head and arthritis with slight osteophytes. Regarding surgical procedures, acromegalic cases were likely to require longer operation time and larger amounts of blood loss compared to the control.

In the quantitative analysis, we first identified a model in which age and body height could predict the functional prognosis of DAA THA in the non-acromegalic cases ($F[2,104] = 6.7$, $P = 0.0017$). We then found that the actual functional outcomes of the acromegalic cases were not significantly different from those predicted by this control-case-based model ($P = 0.18$).

Conclusions

The qualitative analysis shows the atypical joint structures and resultant prolonged operation time and blood loss in the acromegalic cases. However, the quantitative analysis could not find significant difference in prognosis between the acromegalic and non-acromegalic cases. Although these observations and analyses need to be examined in studies with large sample sizes, this work suggests that functional outcomes of DAA THA to acromegalic patients can be comparable to that to non-

acromegalic patients.

Figures

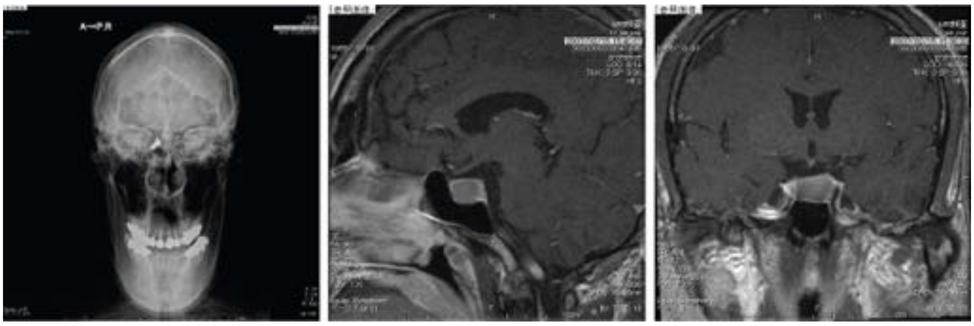

Figure 1

Figure 2

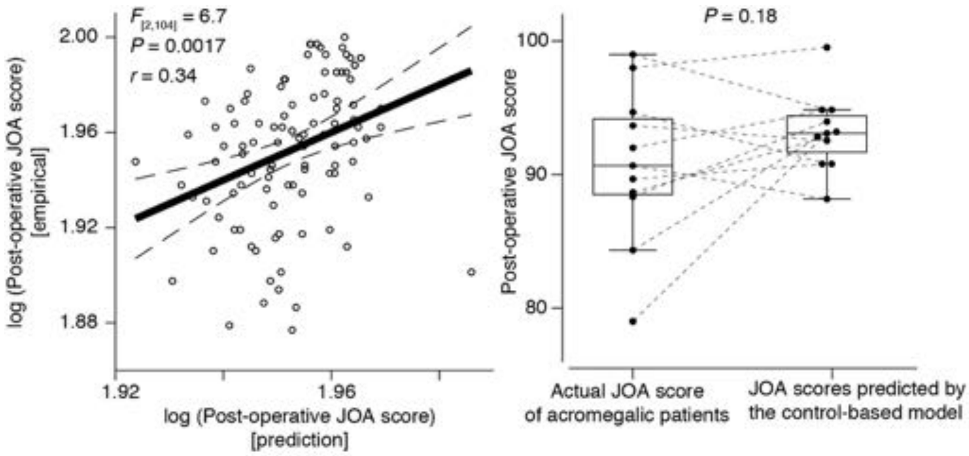

Figure 3

#5567

Results of Total Hip Arthroplasty After Core Decompression With Tantalum Rod for Osteonecrosis of the Femoral Head

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Introduction: Many options have been used to treat early stage osteonecrosis of the femoral head, and core decompression with implantation of a tantalum rod is one method. The purpose of this study was to evaluate clinical and radiological outcomes, as well as potential complications during conversion total hip arthroplasty(THA) in such patients.

Methods: Six male patients (eight hips) underwent THA subsequent to removing a tantalum rod (group I) from April 2010 to November 2011. We retrospectively reviewed the medical records of these patients. We enrolled age- and sex-matched 12 patients (16 hips) during the same period, who had undergone primary THA without a previous operation as the control group (group II).

Results: The mean preoperative harris hip score(HHS) values were 56.5 points and 59.1 points in groups I and II, respectively. The HHS improved to 96.0 points and 97.6 points, respectively, at the 3-year follow-up ($p = 0.172$). Mean operation time was 98.8 min in group I and 77.5 min in group II ($p = 0.006$). Total blood loss volumes were 1193.8 ml and 944.1 ml in groups I and II, respectively ($p = 0.004$). No significant differences were reported in either group in radiological follow-up results. However, one case of squeaking occurred in group I during the follow-up.

Conclusions: No differences were detected between the two groups clinically or radiologically except extended operative time and increased blood loss. However, the incidence of squeaking (one of eight hips) was higher than that of the control group or than that reported previously.

#5536

A Long-Term Follow-Up for Monobloc Implants in Cementless Total Hip Arthroplasty in Patients With Legg-Calve-Perthes Disease

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Abstract

Purpose

The purpose of this study is to evaluate 10-year outcomes in cementless monobloc total hip arthroplasty (THA) in a group of hips with Legg-Calve-Perthes Disease (LCPD).

Methods

We reviewed 71 patients (88 hips) who underwent cementless THA with a diagnose of LCPD from 2003-2009. From a total of 71 patients, 34 men and 37 women with an average age of 49.94 years were involved. Mean follow-up period was ten years.

Results

The mean Harris Hip Score improved significantly from 46.42 to 89.70. Similarly, the postoperative range of motion, Hip dysfunction and Osteoarthritis Outcome Score and SF-12 score also significantly improved. The mean leg lengthening was 22.1mm. During the follow-up, eight complications were noted, including two intraoperative femoral fractures, two sciatic nerve paralysis, two heterotrophic ossifications, one thigh pain and one dislocation. One revision was conducted for a periprosthetic fracture and survivorship at ten years was 98.3%.

Conclusion

These data suggest that the monobloc stem can lead to satisfactory outcomes of the clinical function, radiological evaluation, restoration of normal limb lengths, complications, and survivorship among LCDP patients undergoing total hip arthroplasty.

Keywords

Legg-Calve-Perthes Disease; Monobloc stem; Total hip arthroplasty

#5856

Pelvic Motions Play an Important Role in Contact Location in Total Hip Replacement Bearings

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Introduction

One of the known mechanisms which could contribute to the failure of total hip replacements (THR) is edge contact, where the acetabular cup and the femoral head remain concentric but contact falls partially onto the rim of the cup. Failures associated with edge contact include rim damage[1] and lysis due to altered loading and torques[2]. The previous study[3] on four THR patients showed that the inclusion of pelvic motions in a contact model increased the risk of edge contact in some patients. The aim of current study was to determine whether pelvic motions have the same effect on contact location for a larger patient cohort and determine the contribution of each of the pelvic rotations to this effect.

Methods

Gait data was acquired from five male and five female unilateral THR patients using a ten camera Vicon system (Oxford Metrics, UK) interfaced with twin force plates (AMTI) and using a CAST marker set. All patients had good surgical outcomes as confirmed by patient-reported outcomes and were considered well-functioning, based on elective walking speed. Joint contact forces and pelvic motions were obtained from the AnyBody modelling system (AnyBody Technologies, DK). Only gait cycle regions with available force plate data were considered. A finite element model of a 32mm head on a featureless hemispheric polyethylene cup, 0.5mm radial clearance, was used to obtain contact area from the contact force. A bespoke computational tool[3] was used to analyse patients' gait profiles with and without pelvic motions. The risk of edge contact was measured as a “centre proximity angle” between the cup pole and centre of contact, as well as “proximity angle” between the cup pole and the furthest contact area point (Figure 1). Pelvic tilt, drop and internal-external rotation were considered one at a time and in combinations.

Results

The example output for the current study is presented in Figure 2. The results show that half of the patient's profiles didn't show any substantial difference in the risk of edge contact with and without pelvic motions. The other 50% showed an increase in the maximum proximity values during the second peak of the loading cycle when pelvic motions were considered. For these patients, the combination of tilt and drop was the main influence on the location of contact. The internal-external rotations didn't affect the proximity measures for any patients (Figure 3).

Conclusion

The results of this study suggest that the pelvic motions play an important role in contact location in THR bearings, specifically pelvic tilt and drop, with the most pronounced effect during hip extension. Further tests on larger patient cohorts are required to confirm the trends observed and to explore between-patient variability. The outcomes of this study suggest that pre-clinical testing of THRs should consider the role of pelvic motion, and have implications for establishing surgical positioning safe zones, which are currently based only on dislocation and severe impingement[4, 5].

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Figures

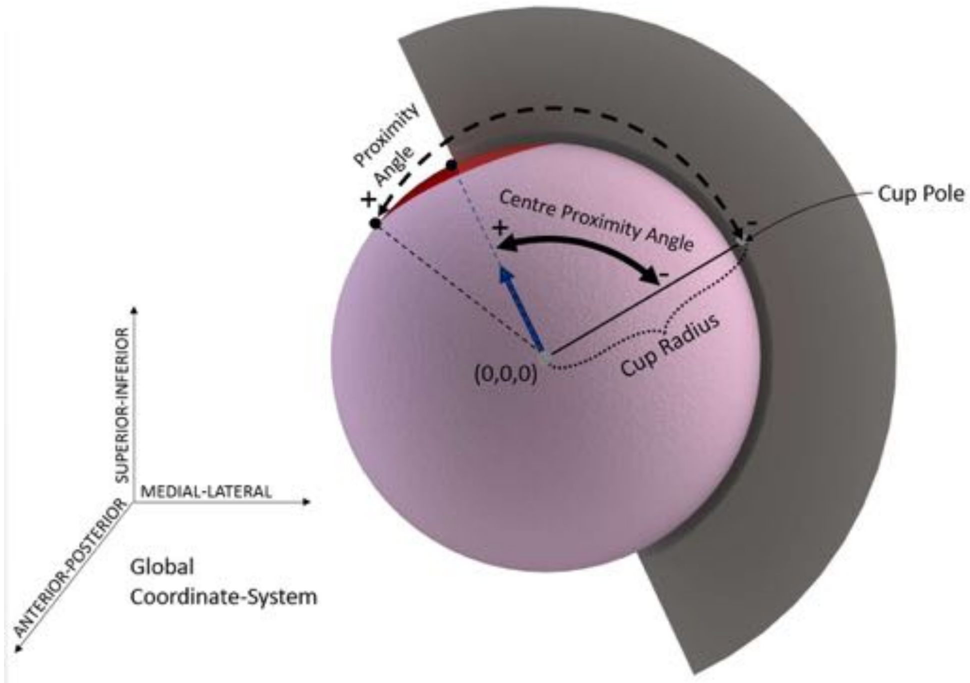

Figure 1

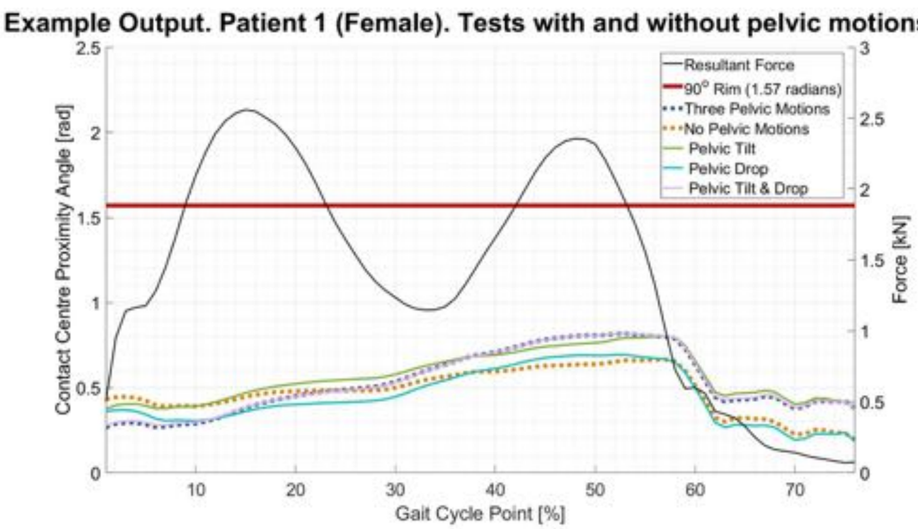

Figure 2

Qualitative analysis of pelvic motion effect on the risk of edge contact duirng second load peak [radians]				
Patient	**Pelvic Motion Effect**	**Pelvic Tilt**	**Pelvic Drop**	**Pelvic Internal & External Rotation**
1 Female	+ 0.17	+ 0.14	+ 0.03	0
2 Female	+ 0.25	+ 0.18	+ 0.07	0
3 Female	none			
4 Female	+ 0.20	+ 0.23	- 0.03	0
5 Female	none			
1 Male	none			
2 Male	none			
3 Male	none			
4 Male	+ 0.32	+ 0.11	+ 0.21	0
5 Male	+ 0.19	+ 0.16	+ 0.03	0

Figure 3

#5663

Total Hip Replacement Patients Stratified by Functionality Present Different Implant Loadings

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Introduction

Preclinical testing of implants considers THR patients a homogenous group; in reality, patients are heterogeneous and previous large cohort studies have explored stratification and identified that THR patients function differently [1]. The wide-spread failure of the ASR hip highlighted the potential importance of patient characteristics [2], and a more robust pre-clinical testing procedure may have improved prediction of outcome. Therefore this study aimed to identify differences in hip contact force (HCF) in THR patients stratified by their functional ability.

Methods

133 THR patients, >12 months post-surgery, underwent 3D kinematic (Vicon, UK) and kinetic (AMTI, USA) analysis whilst walking at self-selected speed. HCF's, normalized by body weight, were computed through multibody modeling (AnyBody Technology, Denmark) during gait and a mean for each patient was calculated from three to five walking trials. Patients were stratified into three functionality groups by distribution around the mean gait speed for the full cohort of 1.1m/s. The low functioning group (LF) comprised cases with a gait speed ≤0.93 m/s (i.e. 1.1m/s ≤1SD), the mid functioning group (MF) comprised cases with a gait speed between 0.94 m/s and 1.25 m/s (cohort mean ± 1SD), while the high functioning group (HF) included cases walking ≥1.26 m/s. Differences between groups were analyzed using one-dimensional statistical parametric mapping [3]. Linear regression was used to test for significant differences across groups. The test statistic SPM{t} was evaluated at each point in the normalized time series, and a critical threshold corresponding to an error rate of $\alpha = 0.05$ was calculated based on random field theory. Supra-threshold clusters with their associated p-values were then identified.

Results

Systematic differences were observed between the different functioning groups throughout the gait cycle. Four different supra-threshold clusters reached or exceeded the critical threshold of $t=3.244$ indicating systematic between-group differences, with the chances of observing similar clusters in repeated random samplings of $p<0.001$. HCF were linearly increasing with functionality from heel strike to foot flat (1^{st} cluster), from terminal stance to initial swing (3^{rd} cluster), and during terminal swing (4^{th} cluster), while they were decreasing for higher functionality during midstance (2^{nd} cluster).

Discussion

Stratification of THR patients by functionality showed significant differences in the contact forces that implants have to withstand during gait. The LF patients displayed a pathological HCF, with a flattening of the typical double hump, indicating that differences can be observed between groups of healthy THR patients. Overall, THR patients are functionally heterogeneous and preclinical testing should reflect differences better than currently required by the ISO-14242 implant testing standard.

Acknowledgments

Funding from the European Union's Seventh Framework Program (FP7/2007-2013), grant agreement GA-310477 (Life-Long Joints)

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Figures

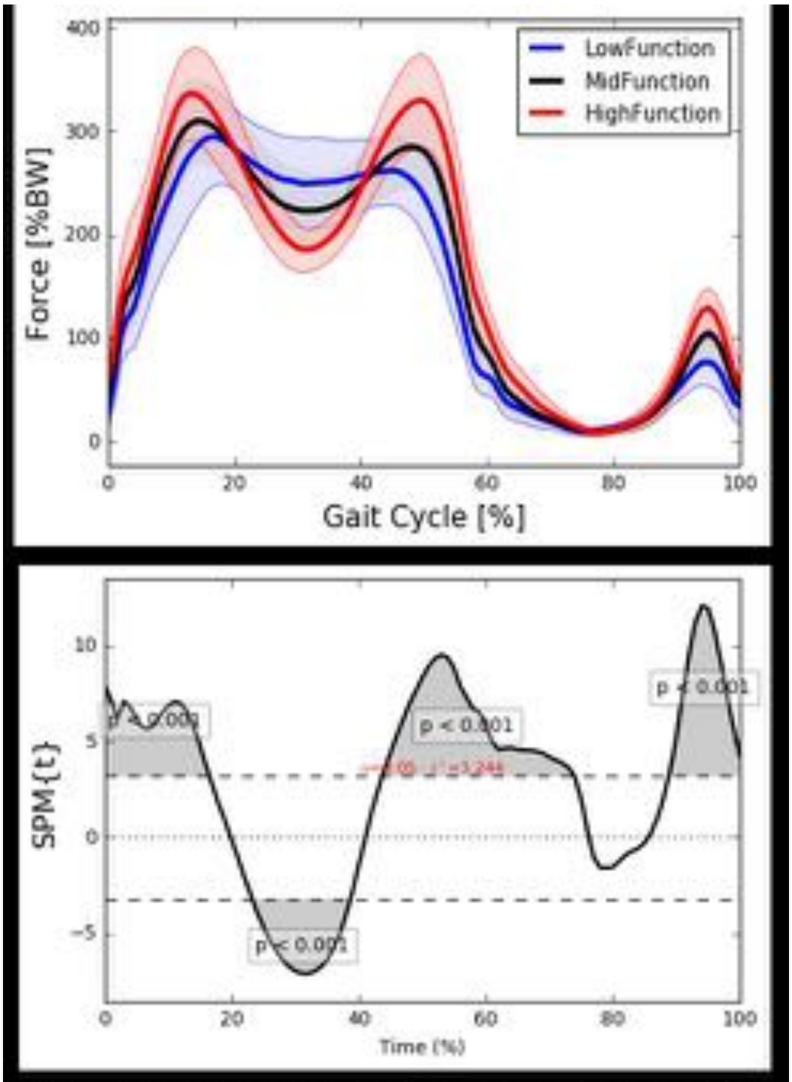

Figure 1: Mean HCF normalized to BW with relative SD during a gait cycle for different functioning groups. Curve analysis performed with statistical parametric mapping showed significant difference in the supra-threshold clusters (SPM(t) > t^* = 3.244).

Figure 1

#6192

Effects of Using a Lipped Liner on the Occurrence of Impingement in THA

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INTRODUCTION: Impingement of total hip arthroplasties (THAs) has been reported to cause rim damage of polyethylene liners, and in some instances has led to dislocation and/or mechanical failure of liner locking mechanisms in modular designs [1]. Elevated rim liners are used to improve stability and reduce the risk of dislocation, however they restrict the possible range of motion of the joint, and retrieval studies have found impingement related damage on lipped liners [2,3]. The aim of this study was to develop a tool for assessing the occurrence of impingement under different activities, and use it to evaluate the effects a lipped liner and position of the lip has on the impingement-free range of motion.

MATERIALS & METHOD: A geometrical model [4] incorporated a hemi-pelvis and femur geometries of one individual [5] with a THA (DePuy Pinnacle® acetabular cup with neutral and lipped liners; size 12 Corail® stem with 32mm diameter head) was created in SOLIDWORKS (Dassault Systèmes) [Fig.1]. Joint motions were taken from kinematic data of activities of daily living that were associated with dislocation of THA [6], such as stooping to pick an object off the floor and rolling over. The femoral component was positioned to conform within the geometry of the femur, and the acetabular component was orientated in a clinically acceptable position (45° inclination and 20° anteversion). Variation in orientation of the apex of the lip was investigated by rotating about the acetabular axes from the superior (0°) in increments of 45° (0°-315°), and compared to a neutral liner [Fig.1].

RESULTS: When a lipped liner was used, implant (neck on acetabular rim) impingement was found to occur when performing sit-to-stand from a normal seat, leg cross and pivot, whereas no impingement occurred with a neutral liner. The presence and position of the lip reduced the impingement free range of motion, compared to the neutral liner. Impingement occurred when the lip was positioned superiorly and anteriorly, when performing most of the activities that were prone to posterior dislocation, and posteriorly, posterior-superiorly and posterior-inferiorly when performing activities prone to anterior dislocation [Fig.2]. During sit-to-stand from a normal seat no impingement occurred when a lipped or neutral liner was used. Bone impingement was observed when the performing the roll activity with both lipped and neutral liners [Fig.2].

DISCUSSION: Impingement was observed more with lipped liners compared to neutral liners, this agrees with the findings of some clinical studies [2,3]. The results indicate that the positioning of the lip influences the possible range impingement-free motion. Considering this and the improved joint stability of using a lipped liner, a balance is required to achieve an optimal range of motion without increasing the risk of dislocation. This tool could potentially to be used to optimise lipped liner design and position, and could assist with the liner selection for patients based on their activities.

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#5873

Does Total Knee Arthroplasty Influence Hip Rotational Range of Motion?

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Introduction:

Progress of knee osteoarthritis (OA) may results in the decrease of the knee range of motion and the malalignment and malrotation of the lower extremity.

Hip rotational range is generally measured from a vertical line, which is drawn from the patella, on supine position with 90° flexion of the hip and knee (Fig.1). The healthy lower leg is usually positioned on this line; however, in varus knee deformity, the lower leg tends to be inside of this line. Thus, it is assumed that the range of hip internal rotation is decreased and that of the external rotation is increased when hip rotational angle is measured from this vertical line with this leg malalignment position. As the aim of total knee arthroplasty (TKA) is to recreate precise bone alignment as well as optimal soft tissue balance, we hypothesized that this alignment correction might alter the ratio of hip internal and external rotations. The purpose of this study was to assess the influence of TKA on hip rotational range in varus knee OA.

Patients and Methods:

Forty-two knees in 38 patients (mean age: 75.6±6.1 years old) with clinical and radiological diagnosis of varus knee OA, who underwent TKA, were enrolled. Patients with valgus knee OA, secondary knee OA due to rheumatoid arthritis and trauma, hip OA, or past history of any surgery on the ipsilateral limb were excluded. Hip rotational range was examined the day before and 3 weeks after TKA, with the above mentioned procedure. Measurement was performed, while one tester passively rotated the patient's hip internally and externally until an end-feel and another measured an angle using a goniometer with the stable arm parallel to the trunk and the mobile arm on the lower leg axis. Thereafter, the variation of hip rotational range with TKA was evaluated.

Results:

All patients showed varus knee deformity with 11.4±5.6Ëš of hip-knee-ankle (HKA) angle preoperatively. Average postoperative HKA angle was -0.6±3.9Ëš. Preoperative hip internal and external rotational angles were 20.3±9.9Ëš and 37.4±10.7Ëš, respectively. After TKA, the internal rotational angle significantly increased to 28.2±10.7Ëš ($p<0.05$) with the mean increasing amount of 12.2±5.9Ëš in 33 knees (78.6%). Conversely, the external rotational angle was decreased to 36.6±9.5Ëš, which, was not significant, and 21 knees (50.0%) actually showed slight increase of the external rotational angle. Consequently, the total overall hip rotational range increase was 6.7±14.7Ëš after TKA. However, there was no correlation with the severity of preoperative varus deformity.

Discussion:

Although the hip joint was not surgically treated, hip rotational range improved after TKA with the increasing of the internal rotational range without significant decreasing of the external rotational range.

The internal rotational range was expected to be improved with the correction of the varus deformity. However, contrary to our hypothesis, the external rotation range did not decrease. The soft tissue balance around the knee was adjusted in TKA, and also the muscle balance of entire lower extremity may have been changed by the correction of the varus deformity. Further investigations are necessary, however, the variation of the soft tissue balance may be considered to affect hip rotational range after TKA.

Conclusion:

TKA can influence hip rotational range of motion.

Figures

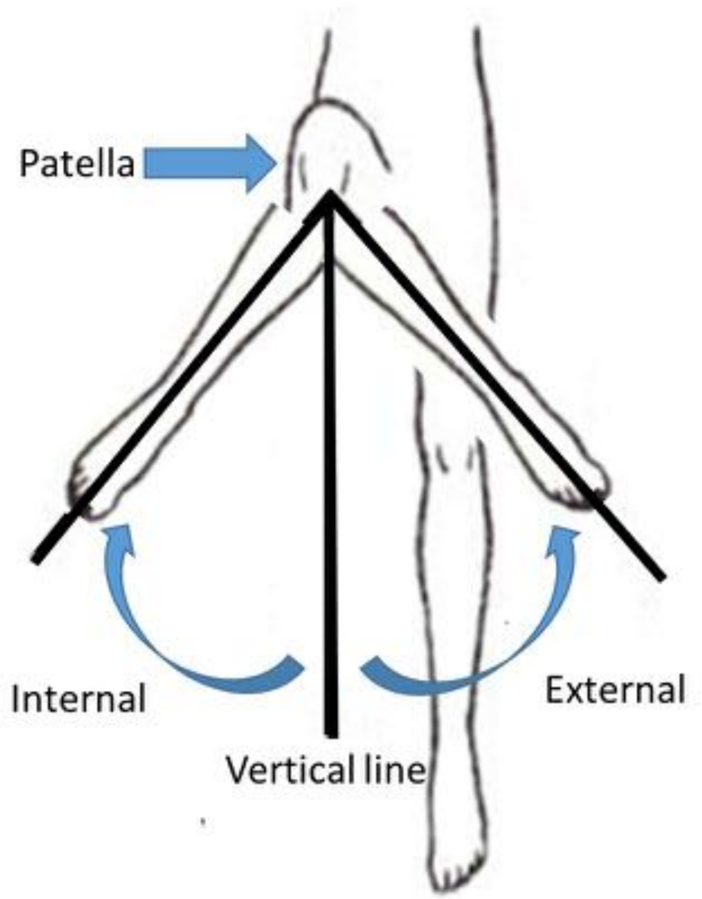

Figure 1

Contact Surface Pathways in Total Hip Replacement Patients Stratified by Body Mass Index

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Introduction

Total hip replacement (THR) patients are often considered a homogenous group whereas in reality, patients are heterogeneous. Variation in revision rates between patient groups suggest that implants are exposed to different environmental conditions in different patients[1]. Previous reports suggest that for every unit increase of BMI, there is a 2% increased risk of revision of a THR[2]. The aim of this study was to better understand the effect of patient-specific characteristics such as BMI on hip motions and to explore the possible impact on wear.

Methods

137 THR patients, at least 12 months post-surgery, underwent 3D kinematic (Vicon, Oxford, UK) and kinetic (AMTI, USA) analysis whilst walking at self-selected walking speed. 3D kinematic data were then mapped onto a modelled femoral cup at 20 pre-determined points to create pathways for femoral head contact, which were then quantified by deriving the aspect ratio (AR). Patients were stratified into three groups determined by BMI scores; healthy weight (BMI ≤25 kg/m^2) (n=34); overweight (BMI >25kg/m^2 to ≤ 30 kg/m^2) (n=66) and obese patients (BMI > 30 kg/m^2) (n=37). Comparisons were made using 95% confidence intervals (CI) and one way ANOVAs.

Results

The healthy weight strata demonstrated a minimum flexion angle of 0.59°(CI -2.15 to 3.32), compared to overweight 1.12°(CI 0.99 to 2.11) and obese strata 1.37°(-0.72 to 3.46). The healthy weight strata exhibited a lower frontal ROM 7.91° (CI 7.02 to 8.80) (p<0.000) compared to the overweight (9.42°, CI 8.76 to 10.08) and obese strata (9.79°; CI 9.08 to 10.50). No differences between strata were observed in the transverse plane. The real-world gait inputs resulted in a lower aspect ratio for all three patient groups compared to the ISO standard AR of 3.86. There was a trend towards a higher AR in patients with a lower BMI (Figure 1). Obese patients had a reduced AR of 3.33 (CI 3.08 to 3.58) compared to the overweight and healthy weight patients, demonstrating AR of 3.36(CI 3.21 to 3.52) and 3.48 (CI 3.25 to 3.70), respectively.

Discussion

There were few hip kinematic differences between BMI strata, except for a lower frontal ROM in the healthy weight patients. There was a resulting trend towards an increased AR in the healthy weight group. Notwithstanding the effect of contact force which was not modelled in this study, increased AR in the healthy weight group might assist long molecule entrainment and hence reduce risk of polyethylene wear for equivalent levels of activity. These results highlight the conservative nature of the ISO standard and provide a possible link between kinematics and the observed increased in revision rates in patients with high BMI.

References

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Acknowledgement

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Figures

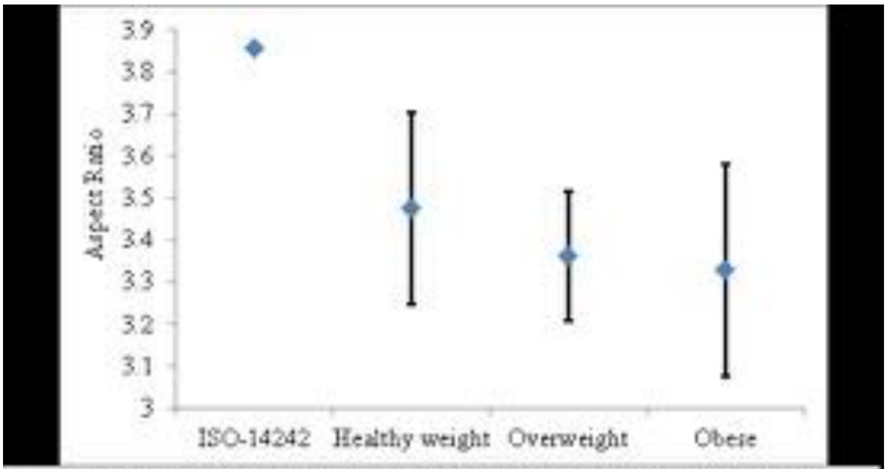

Figure 1 . Mean aspect ratios for all patient groups during one gait cycle compared to ISO-14242

Figure 1

#5850

In Vivo Comparision of Normal Hip Kinematics With Degenerative Hips Before and After Tha

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Introduction

Hip osteoarthritis can be debilitating, often leading to pain, poor kinematics and limiting range of motion. While the in vivo kinematics of a total hip arthroplasty (THA) are well documented, there is limited information pertaining to the kinematics of native, non-arthritic (normal) hips and degenerative hips requiring a THA.

The objective of this study is to evaluate and compare the in vivo kinematics of the normal hip with pre-operative, degenerative hips and post-operative THA.

Methods

Twenty subjects, ten having a normal hip and ten having a pre-operative, degenerative hip that were analyzed before surgery and then post-operatively after receiving a THA. Each subject was asked to perform gait while under mobile fluoroscopic surveillance. Normal and pre-operative degenerative subjects underwent a CT scan so that 3D models of their femur and pelvis could be created. Using 3D-to-2D registration techniques, the hip joint kinematics were derived and assessed. Femoral head and acetabular cup rotational centers were derived using spheres. The centers of these spheres were used to obtain the femoral head sliding distance on the acetabular cup during the activity. The patient-specific reference femoral head values were obtained from the subjects' CT scans in a non-weight bearing situation.

Results

Overall, 0% of the normal subjects experienced femoral head sliding (FHS) within the acetabulum, and 33% of the degenerative subjects experienced FHS. The degenerative hips experienced an average maximum sliding of 0.902 ± 0.864 mm. Further evaluation seems to indicate that the femoral head ligament played a significant role in hip separation. If this ligament was not functioning, it appeared that the femoral head experienced more abnormal motion. Therefore, degenerative hip subjects having an intact femoral head ligament did not experience femoral head sliding of their femoral head within the acetabulum.

A further analysis was then conducted to assess the contact area between femoral head and acetabular cup (Figure 1). After THA implantation, subjects experienced greater abnormal hip motion leading to hip separation.

Discussion

Overall, our current analysis has revealed trends that degenerative hips experience more abnormal hip kinematics that lead to higher bearing surface forces and stresses. It was interesting to note that the intact femoral head ligament did stabilize the hip joint leading to no femoral head sliding. Therefore, further research needs to be conducted to determine the role of the femoral head ligament and degeneration of the hip joint. Also, it is worth noting that the maximum displacement usually occurs during swing phase of the gait, just before heel-strike for degenerative hips, similar to total hip arthroplasty, evaluated in previous fluoroscopic studies. Further investigation is being conducted to evaluate component placement for the THA subjects, comparing their motion pre and post-operatively.

#6072

Minimizing Bone Strain While Maximising Fixation During Impaction of the Acetabular Cup

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Initial stability of cementless components in bone is essential for longevity of Total Hip Replacements. Fixation is provided by press-fit: seating an implant in an under-reamed bone cavity with mallet strikes (impaction). Excessive impaction energy has been shown to increase the risk of periprosthetic fracture of bone. However, if implants are not adequately seated they may lack the stability required for bone ingrowth. Ideal fixation would maximise implant stability but would minimise peak strain in bone, reducing the risk of fracture.

This in-vitro study examines the influence of impaction energy and number of seating strikes upon implant push-out force (indicating stability) and peak dynamic strain in bone substitute (indicating likelihood of fracture). The ratio of these factors is given as an indicator of successful impaction strategy.

A custom drop tower with simulated hip compliance was used to seat acetabular cups in 30 Sawbone blocks (Figure 1). 3 impaction energies were selected; low (0.7j), medium (4.5j) and high (14.4j), representing the wide range of values measured during surgery. Each Sawbone was instrumented with strain gages, secured on the block surface close to the acetabular cavity (Figure 1). Strain gage data was acquired at 50khz with peak tensile strain recorded for each strike. An optical tracker was used to determine the polar gap between the cup and Sawbone cavity during seating. Initially 10 strikes were used to seat each cup. Tracking data were then used to determine at which strike the cups progressed less than 10% of the final polar gap. This value was taken as number of strikes to complete seating. Tests were repeated with fresh Sawbone, striking each cup the number of times required to seat. Following each seating push-out forces of the cups were recorded using a compression testing machine.

10, 5 and 2 strikes were required to seat the acetabular cups for the low, medium and high energies respectively. It was found that strain in the Sawbone peaked around the number of strikes to complete seating and subsequently decreased. This trend was particularly pronounced in the high energy group (Figure 2). An increase in Sawbone strain during seating was observed with increasing energy (270+/-29με [SD], 519+/-91με and 585+/-183με at low, medium and high energies respectively, Figure 3). The highest push-out force was achieved at medium strike energy (261+/-46N). The ratio between push-out and strain was highest for medium strike energy (0.50+/-0.095 N/με). Push-out force was similar after 5 and 10 strikes for the medium energy strike. However push-out recorded at ten strikes for the high energy group was significantly lower than for 2 strikes (<40+/-19 N, $p<0.05$).

These results indicate that a medium strike energy with an appropriate number of seating strikes maximises initial implant stability for a given peak bone strain. It is also shown that impaction with an excessive strike energy may greatly reduce fixation strength while inducing a very high peak dynamic strain in the bone. Surgeons should take care to avoid an excessive number of impaction strikes at high energy.

Figures

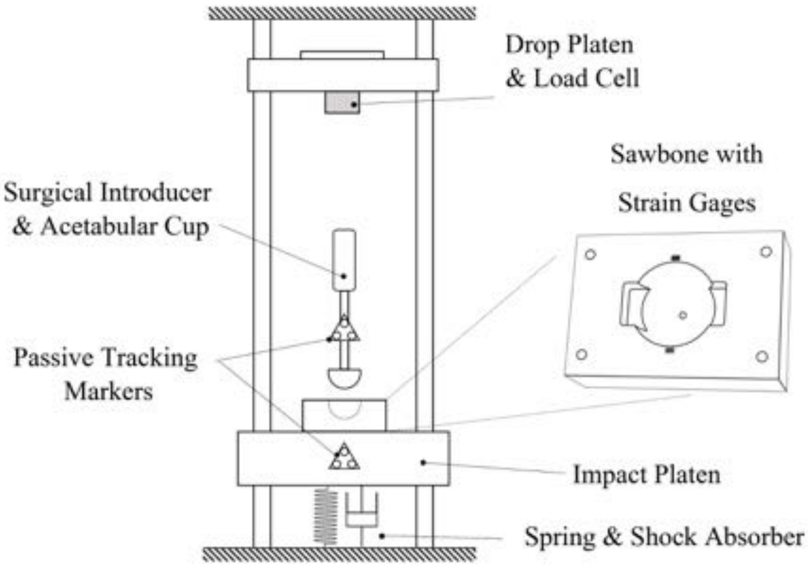

Figure 1: Experimental Setup

Figure 1

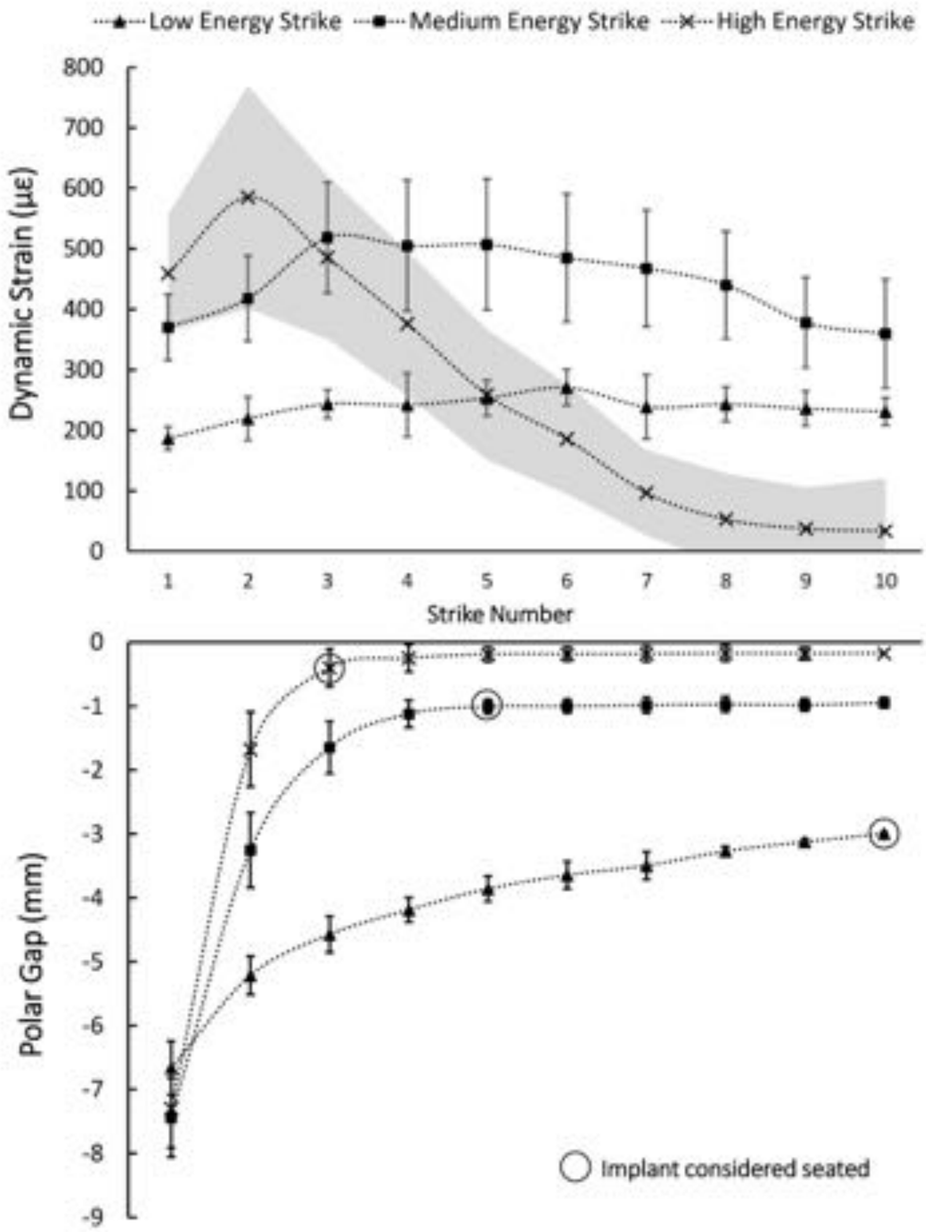

Figure 2: Dynamic Sawbone Strain and Polar Gap during Seating of Acetabular Component for each Energy Level

Figure 2

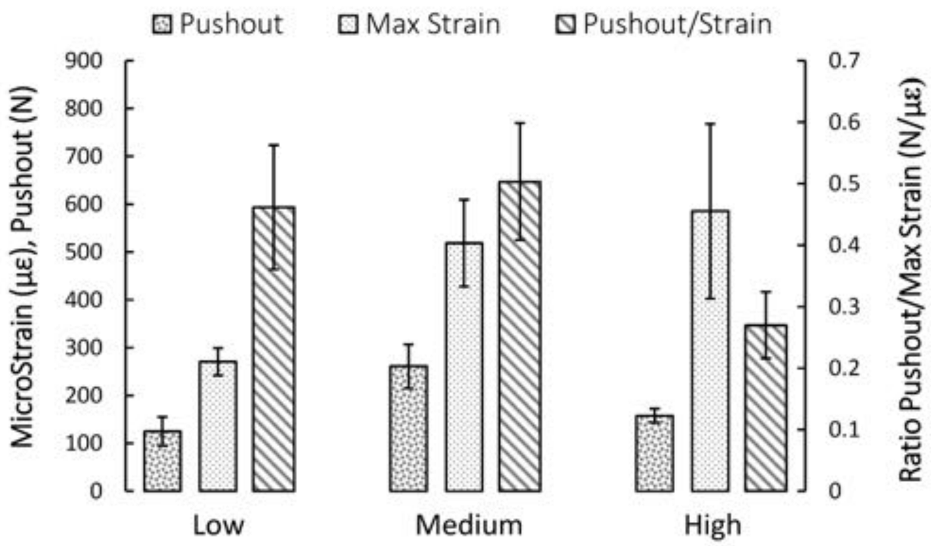

Figure 3: Maximum Microstrain, Pushout Force (after 10, 5 and 2 strikes respectively) and Ratio for Low, Medium and High Energy Levels

Figure 3

#5703

Tranexamic Acid Reduces Transfusions Rates in Obese and Super Obese Patients Undergoing Total Joint Arthroplasty

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Background: While tranexamic acid (TXA) has been well shown to reduce blood loss after joint replacement surgery, little is known regarding its effectiveness in obese patients. The aim of this study was to evaluate the effect of TXA changes in hematocrit and hemoglobin levels as well as incidence of packed red blood cell (pRBC) transfusions in obese patients undergoing total joint arthroplasty (TJA).

Material and Methods: Between January 2014 and May 2015, 420 consecutive primary joint replacements were performed by two surgeons at our institution. 157 patients (THA=29; TKA=128) were obese with a body mass index (BMI) greater than or equal to 30 kg/m^2. Medical records were reviewed and identified that TXA was utilized in 85 (54.1%) arthroplasties [study group] and was compared to a consecutive series of 72 (45.9%) TJAs [control group]. TXA was given intravenously (IV) in two doses: (1) one gram prior to incision and (2) one gram at the time of femoral preparation in THA or prior to cementation in TKA. Changes in hemoglobin and hematocrit levels, number of pRBC transfusions, and occurrence of thrombolytic events were recorded.

Results: The changes in hematocrit (7.2% vs. 8.1%) and hemoglobin levels (3.0 g/dl vs. 3.3 g/dl) were less for group that received TXA than the control group, albeit not significantly ($p=0.100$ and $p=0.278$, respectively). Within the control group 26 (36.1%) patients required a pRBC transfusion with a mean of 2.0 units per patient (range:1-5); whereas, only 8 (9.4%) patients with TXA required a mean of 1.6 units per patient (range:1-2 units). The use of TXA significantly reduced the incidence of pRBC transfusions, especially in TKA ($p<0.001$). Sub-analyses revealed that transfusion rates were even more significantly reduced by TXA in obesity type II and III. Two pulmonary emboli were reported in the group that did not receive TXA, whereas no thrombolytic events were reported in the group that did receive TXA.

Conclusion: Utilization of TXA significantly reduced the rate of pRBC transfusions in obese patients.

#5537

Oral Versus Intravenous Versus Topical Tranexamic Acid in Primary Hip Arthroplasty: A Prospective, Randomized, Double-Blind, Controlled Study

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Abstract

Background

Tranexamic acid (TXA) has demonstrated efficacy in reducing blood loss, reduction of hemoglobin, and blood transfusion requirements in primary total hip arthroplasty (THA). The optimal mode of TXA administration for patients undergoing primary THA is unclear. The purpose of this randomized controlled trial was to determine whether oral administration of TXA was superior to intravenous or topical routes in these patients.

Methods

In this double-blinded placebo-controlled trial, patients undergoing primary THA were randomized to oral (2 g TXA orally 2 hours preoperatively), intravenous (20 mg/kg intravenous TXA bolus 5 minutes before the incision) or topical (2 g TXA applied topically) TXA groups. The primary outcome was the reduction of hemoglobin. Secondary outcomes included blood loss, transfusion rate, cost of TXA (Chinese yuan (¥); in 2017, ¥1 = $0.147), and adverse events.

Results

One hundred and eighty patients were randomized into the three groups. Demographic characteristics were similar among the groups. The mean reduction of hemoglobin was similar among the oral, intravenous, and topical groups (3.48 ± 1.32g/dL, 3.58 ± 1.07g/dL, and 3.66 ± 1.26g/dL, respectively). Similarly, the mean total blood loss did not differ significantly among the three groups. The oral group incurred the lowest TXA cost (¥480) compared with that in the intravenous (¥3329.28) and topical (¥3540) groups (P = 0.01). None of the patients sustained a deep venous thrombosis (DVT), pulmonary embolism (PE) or an infection.

Conclusion

The blood-sparing efficacy of oral TXA is comparable to that of the intravenous and topical forms. Oral TXA is recommended because of its cost-benefit superiority and ease of administration.

Keywords Tranexamic acid; Intravenous; Topical; Oral; Total hip arthroplasty; Blood loss

#5683

INTRA-ARTICULAR TRANEXAMIC ACID to REDUCE BLOOD LOSS in CONCURRENT BILATERAL TOTAL KNEE ARTHROPLASTY a Prospective, Randomised Double Blind Study

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Abstract: *The effect of intra-articular tranexamic acid on blood loss in concurrent bilateral total knee arthroplasty was studied in 60 patients in double blind fashion; one knee receiving tranexamic acid, the other knee receiving physiological saline acting as control. A single surgeon performed all operations utilising the same surgical technique and prosthesis. Mean blood loss from intra-articular drains was not significantly different, being 141ml in the tranexamic acid group and 163ml in the control group. Circumferential leg measurements at levels above, through and below the knees were not significantly different between groups on day two post-operatively compared to pre-operatively. Intra-articular tranexamic acid instillation did not lead to a significant reduction in blood loss in these patients.* ***Keywords:*** *bilateral total knee arthroplasty, blood loss, intra-articular tranexamic acid.*

#6049

The Efficacy and the Effect of Intra-Articular Injection of Tranexamic Acid in Total Knee Arthroplasty

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Tranexamic acid was intra-articularly injected in total knee arthroplasty (TKA) to reduce blood loss and transfusion. Blood loss and deep vein thrombosis are important complications after TKA.

A retrospective cohort study was conducted with two groups. To determine the safety and efficacy of intra-articular tranexamic acid in TKA, the authors searched various databases for relevant randomized controlled trials. Mean difference (MD) in total blood loss, risk ratio (RR) for transfusion, and complication rate in the tranexamic acid-treated group vs the placebo group were calculated. Seven key values, including 635 patients from 2012 to 2017, were identified.

The pooled results showed a positive effect of tranexamic acid in all treatment groups, with significant reduction in total blood loss. However, there was significant heterogeneity in the finding among studies. The pooled results indicated that 4.5% of tranexamic acid-treated patients required transfusion compared with 31.3% of placebo-treated patients. This difference was significant. There was no significant difference between the groups in the incidence of deep venous thrombosis (DVT) or pulmonary embolism (PE).

In all, intra-articular tranexamic acid significantly reduced total blood loss, drainage, reduction of hemoglobin, and the need for transfusion without increasing the incidence of DVT and PE. Intra-articular tranexamic acid is safe and efficacious in TKA.

#5598

The post-operative determination of hemoglobin level in not necessary after TKA

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INTRODUCTION

Postoperative hemoglobin determination after total knee arthroplasty (TKA) is considered essential to detect and possibly treat significant anemia. However, the usefulness of this systematic procedure has never been validated. The hypothesis of this study was that this determination performed the day after surgery did not provide clinically useful information when modern blood saving procedures are used.

METHODS

All patients undergoing TKA between October 2016 and October 2017 were eligible for a prospective observational study. Patients operated for unilateral primary TKA were selected. All patients received a preoperative injection of tranexamic acid (2 g IV). Surgery was performed under general anesthesia by one of two surgeons experienced in knee prosthetic surgery with a standardized operative technique. All procedures were performed under navigation control without violation of the femoral and tibial medullary canal. All procedures were performed under inflated tourniquet before the incision at 300 mm Hg and deflated after dressing preparation. No blood recovery system was used. No drainage was left.

The usual demographic criteria, the preoperative hemoglobin level and the hemoglobin level at the day following surgery were collected. The possible existence of clinical signs of anemia (tachycardia, asthenia, malaise ...) after the intervention was recorded. The need for allogenic transfusions during or after the procedure was noted. The transfusion indications were previously arbitrarily established: hemoglobin determination below 9g/dl and/or presence of clinical signs of anemia.

RESULTS

108 patients were included: 42 men and 66 women, with an average age of 70 ± 10 years, with an average body mass index of 30 ± 6 kg/m². The preoperative hemoglobin level was 13.8 ± 1.2 g/dl, and all patients had a rate greater than 11 g/dl. 7 patients (6%) received allogenic transfusion during the procedure (2 pockets). The hemoglobin level at the first post-operative day was 11.6 ± 1.3 g/dl, and all but one patient had a hemoglobin level greater than 9 g/dl. 12 patients (11%) had clinical signs of anemia the day after the procedure; 2 had a hemoglobin level of less than 10 g/dl. 5 patients (5%) received allogenic transfusion during the early postoperativephase: the 2 previous patients (2 pockets), one patient with functional renal failure, and two patients for no obvious reason.

DISCUSSION

The determination of hemoglobin level in the immediate post-operative course after TKA did not provide a significant indication of the possible need for allogenic blood transfusion when modern blood saving procedures are used and there are no clinical signs of anemia. The cost of this procedure is certainly low, but not negligible in a period of constrained financing. It therefore seems logical to eliminate this routine dosage in the absence of clinical signs of anemia

#5622

Prospective Evaluation of a Non-Invasive Hemoglobin Measurement System in Total Joint Arthroplasty

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Background:

Non-invasive hemoglobin measurement was introduced to potentially eliminate blood draws postoperatively. We compared the accuracy and effectiveness of a non-invasive hemoglobin measurement system with a traditional blood draw in patients undergoing total joint arthroplasty.

Methods:

After IRB approval, 100 consecutive patients undergoing primary total hip or knee arthroplasty had their hemoglobin level tested by both traditional blood draw and a non-invasive hemoglobin monitoring system. Results were analyzed for the entire group, further stratifying patients based on gender, race, surgery (THA versus TKA), and post-operative hemoglobin level. Finally, we compared financial implications and patient satisfaction with the device. Paired t-test with 0.05 conferring significance was used. Stratified analyses of the absolute difference between the two measures were assessed using Mann-Whitney test. To assess the level of agreement between the two measures, the concordance correlation coefficient (CCC) was calculated.

Results:

Mean blood-draw hemoglobin value on POD1 was 11.063 ± 1.39 g/dL and 11.192 ± 1.333 g/dL with the non-invasive device. For all patients, the mean absolute difference between the two methods was 0.13 g/dL ($p = 0.30$). The CCC between the two methods was 0.58, conferring a moderate to strongly positive linear relationship (Figure 1).

Comparing patients by gender, race, or surgery, the median difference between the two methods was not significantly different ($p>0.28$). However, we did find a significant difference in between the digital reading and blood draw if the patient's hemoglobin was <10 g/dL (>10 g/dL = 0.8 g/dL vs < 10 g/dL= 1.2 g/dL, $p = 0.03$). See Figure 2 for a full summary of the data.

Non-invasive measurement was preferred by 100% of patients with a mean VAS score of 0/10. Additionally, the cost savings with the non-invasive system was $16.50 per patient.

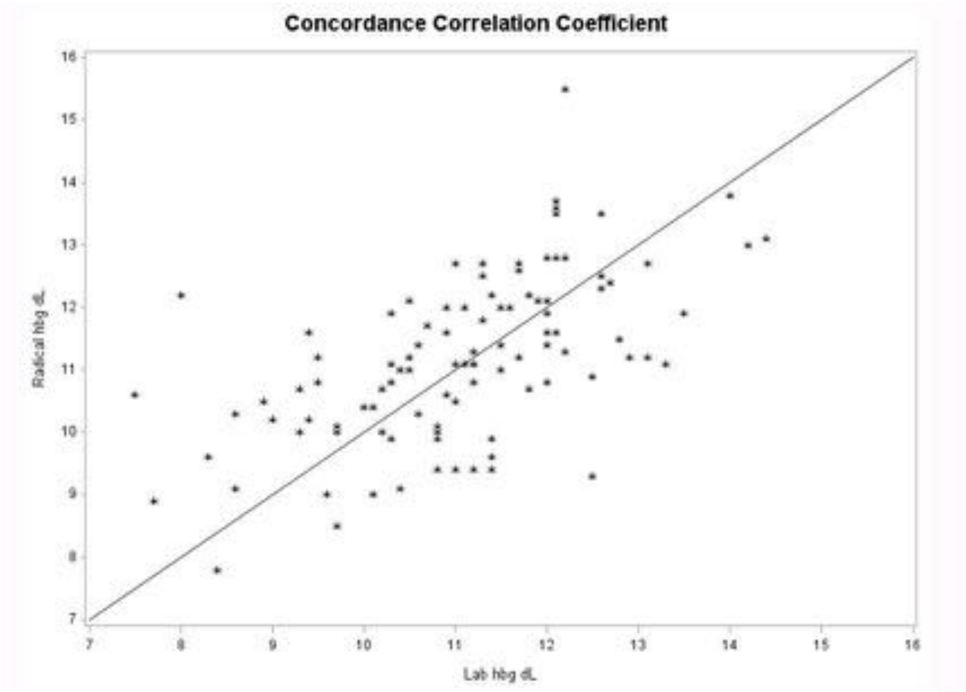
Discussion:

Overall, there was no significant difference between the hemoglobin level obtained by traditional laboratory methods versus the Masimo Radical-7 system on post-operative day #1 in patients who underwent total joint arthroplasty. In the minority of patients (19%) who had a hemoglobin level of less than 10 g/dL, the difference between the two methods was statistically significant. Additionally, 100% of patients preferred the Masimo device to a traditional blood draw and the Masimo device was substantially cheaper. While further investigation of non-invasive hemoglobin monitoring systems is necessary, particularly in patients with a post-operative hemoglobin of less than 10 g/dL, our study shows that the Masimo Radical-7 device provides an accurate, preferable, and less expensive alternative to a traditional blood draw after total joint replacement.

Conclusion:

Overall, the non-invasive hemoglobin monitoring system offered a similar hemoglobin reading to the standard lab-draw reading, while improving satisfaction and lowering cost. The system relies on adequate perfusion for measurement, and our study demonstrated that lower hemoglobin values may reduce finger-tip perfusion and affect the hemoglobin reading.

Figures



[Figure 1](#)

	n	Absolute Difference [median (q1, q3)]	p-value
Gender			
Female	32	0.85 (0.45, 1.55)	
Male	68	0.8 (0.4, 1.35)	0.50
Ethnicity			
Caucasian	69	0.7 (0.4, 1.4)	
African American	31	1 (0.6, 1.5)	0.28
Surgery			
TKA	60	0.85 (0.4, 1.45)	
THA	40	0.8 (0.5, 1.3)	0.55
Hgb			
≤ 10 g/dL	81	0.8 (0.4, 1.3)	
>10 g/dL	19	1.2 (0.6, 1.7)	0.03

Figure 2

#5507

Comparison of the Incidence of Venous Thromboembolism Following Total Hip Arthroplasty With Tendon-Preserving Approaches and a Direct Lateral Approach

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[Purpose] In total hip arthroplasty (THA), the direct anterior approach (DAA) and OCM (modified Watson-Jones approach) are tendon-preserving approaches. Since tendons are not resected, there are expectations for early functional recovery postoperatively and a decreased incidence of venous thromboembolism (VTE) from shortened periods of bed confinement. However, we encountered many cases of VTE soon after DAA was introduced in our department. This study compared the incidence of VTE following THA with DAA, OCM, and a lateral approach.

[Methods] THA was performed in two hospitals between January 2014 and July 2016. Patients were divided into a DAA group of 11 patients, 11 hips (Group A), an OCM group of 31 patients, 34 hips (Group B), and a lateral approach group of 75 patients, 81 hips (Group C). Examinations for VTE were done at 2 postoperative weeks using contrast enhanced CT and venous ultrasound of the legs. Hand massage of the legs was performed soon after surgery in all patients, but anticoagulant therapy was not used.

[Results] Group A consisted of 2 men and 9 women, Group B of 6 men and 25 women, and Group C of 17 men and 58 women, with mean ages at the time of surgery of 67.5±13, 64.7±12, and 62.4±11 years old, respectively. The incidence of VTE was 36.4% (4 patients) in Group A, 12.9% (4 patients) in Group B, and 9.9% (8 patients) in Group C. This was significantly higher in Group A than in Group C ($P = 0.04$, χ^2 test). In Group A, there were no differences in sex, BMI, age at surgery, or operational time with and without VTE, but VTE occurred soon after the DAA introduction in 3 of the 4 patients in whom it developed. After THA with OCM, all four of the patients in whom VTE occurred were among the 17 patients in the initial introduction period of OCM.

[Discussion] Although no consensus has been reached on the incidence of VTE with tendon-preserving approaches, stasis in the venous circulation from long compression of the femoral vein due to intraoperative leg position or intraoperative retractors is thought to be one cause. Careful postoperative monitoring for VTE and active anticoagulant therapy, especially in the initial introduction period of a technique until surgeons have mastered it, may be necessary.

#5499

The Effect Preoperative Discontinuation of Antiplatelet Agent on Blood Loss and Bleeding Related Complication in Total Knee Arthroplasty

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Purpose: This study aimed to investigate the effects of discontinuing antiplatelet agents before total knee arthroplasty on postoperative blood loss and bleeding related complications.

Materials and Methods: A database of all patients undergoing total knee arthroplasty between 2012 and 2016 was analyzed. Demographic, surgical and complete blood workup data were collected. Retrospectively, total 452 cases of total knee arthroplasty were enrolled within our inclusion criteria and classified into 327 patients of discontinuing antiplatelet agent group (acetylsalicylic acid: 213 patients, thienopyridine: 114 patients) and 115 patients of continuing group (acetylsalicylic acid: 81 patients, thienopyridine: 34 patients). For another analysis, we investigated preoperative bleeding time and patients were classified into 139 abnormal bleeding time (ANBT) group and 313 normal bleeding time (NBT) group (normal range: Bleeding time 81-192 sec). We examined hemoglobin concentration and hematocrit at three points in time preoperatively, 24 hours and 48 hours postoperatively. We compared groups of patients in terms of total blood loss, postoperative drained blood loss, hidden blood loss, visible blood loss and thrombocytopenia (platelet count <100×103/μL) and investigated whether patients had had any gastrointestinal bleeding, hematuria, nasal bleeding, hematoma requiring re-operation due to bleeding.

Results: There were no significant differences between the discontinuing group and continuing group in the hemoglobin concentration at 24 hours and 48 hours postoperatively (p=0.171, p=0.247), hematocrit at 24 hours and 48 hours postoperatively (p=0.128, p=0.225). No statistically significant differences between these two groups in the postoperative drained blood loss (p=0.281), the visible blood loss (p=0.323), hidden blood loss (p=0.245) and total blood loss (p=0.526) were found. There were no significant differences between NBT group and ANBT group in the hemoglobin concentration at 24 hours and 48 hours postoperatively (p=0.198, p=0.183), hematocrit at 24 hours and 48 hours postoperatively (p=0.101, p=0.293). No statistically significant differences between these two groups in the postoperative drained blood loss (p=0.281), the visible blood loss (p=0.125), hidden blood loss (p=0.121) and total blood loss (p=0.526) were found. Of the 452 cases, eleven (3.336%) deep vein thrombosis were found in the discontinuing groups and four cases(3.478%) in continuing group. Twelve (3.846%) deep vein thrombosis were found in the NBT group and three(0.7%) cases in ANBT group. There were one (0.869%) case of upper gastrointestinal bleeding in continuing group and there no case of hematuria, nasal bleeding, or hematoma requiring reoperation.

Conclusion: Discontinuing or continuing anti-platelet agents undergoing TKA has no effect on postoperative blood loss and bleeding related complication. Our data support perioperative continuation of aspirin or clopidogrel intake in patients undergoing TKR.

Comparison of Oral Versus Intra-Articular Tranexamic Acid in Enhanced-Recovery Primary Total Knee Arthroplasty Without Tourniquet Application: A Randomized Controlled Trial

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ObjectiveAlthough randomized controlled trials have confirmed oral tranexamic acid (TXA) can provide similar blood-sparing efficacy compared with intravenous (IV) TXA in total knee arthroplasty (TKA), some concerns do remain about thromboembolic events after such systemic administration. Many studies have confirmed that intra-articular (IA) application of TXA can show similar blood-saving efficacy with minimal levels of systemic absorption compared with IV TXA. However, it remains unclear whether the efficacy and safety of oral TXA administration is equal to or less than that of IA administration in TKA without the use of a tourniquet and drain. Thus, this study was to verify non-inferior efficacy and safety of oral TXA compared with IA TXA in primary TKA.

MethodsA double-blind, randomized, controlled trial was performed to compare three oral doses of TXA (2 g of TXA 2 h before incision, and 1 g of TXA 6 and 12 h after surgery, respectively) with IA TXA (3 g of TXA in 100 mL of saline solution). One hundred forty-seven patients scheduled for TKA were randomized to one of the two interventions. The primary outcome was total blood loss. The secondary outcomes included reduction of hemoglobin concentration, clinical outcomes, blood coagulation values, thromboembolic complications, and transfusion rates.

ResultsThe mean total blood loss was 788.8 mL in the oral TXA group compared with 872.4 mL in the IA TXA group, with no statistical significance ($p > 0.05$). There were no significant differences in reduction of hemoglobin level, blood coagulation level, and clinical outcomes. The transfusion rates were 4% in oral group and 5% IA group, respectively. Also, no significant differences were identified in thromboembolic complications.

ConclusionOral TXA according to the described protocol demonstrated non-inferiority for primary TKA, with no safety concerns and a greatly reduced cost, compared with the IA TXA. This randomized controlled trial supports the oral administration of TXA in TKA.

#5881

Blood-Sparing Efficacy of Multiple Doses of Oral Tranexamic Acid in Enhanced-Recovery Primary Total Knee Arthroplastya Randomized Controlled Trial

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Aims The purpose of this study was to identify the most effective regimen of multiple boluses of oral tranexamic acid(TXA) in achieving maximum reduction of blood loss in total knee arthroplasty (TKA).

Patients and Methods In this randomized controlled trial, 200 patients were randomized to receive a single dose of 2.0 g of TXA orally 2 hours preoperatively (group A), a single dose followed by 1.0-g TXA orally three hours postoperatively (group B), a single dose followed by 1.0-g TXA orally three and nine hours postoperatively (group C), or a single dose followed by 1.0-g TXA orally three, nine, and fifteen hours postoperatively (group D). All patients followed a routine enhanced-recovery protocol. The primary outcome was the calculated total blood loss. Secondary outcomes were hidden blood loss (HBL), reduction of hemoglobin, transfusion rate, and adverse events.

Results The group C (661.1 mL; standard deviation (SD) = 262.4) and group D (597.7 mL; SD = 219.6) had significantly lower mean total blood loss compared with group A and group B. The mean HBL was signiï¬cantly lower in group B (699.2 mL), group C (533.1 mL), and group D (469.9 mL) than in group A ($P = 0.006$, $P < 0.001$, and $P < 0.001$, respectively). The group C (2.22 mL; SD = 0.91) and D (2.04 mL; SD = 0.95) had lower reduction in hemoglobin than group A and group B. However, no differences were identified between group C and group D regarding the three parameters.

ConclusionThe additional postoperative two- and three-dose oral TXA regimens produced a significant reduction in blood loss. The postoperative two-dose regimen is the least necessary regimen for clinical efficacy in primary unilateral TKA. Three-dose oral TXA regimen produced maximum reduction of blood loss.

#5978

Three-Year Outcomes of a Highly Porous Acetabular Shell in Primary Total Hip Arthroplasty

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Introduction: Initial fixation and stability of acetabular implants are dependent on implant designs and materials, which influence long-term survivorship. A porous three-dimensional shell constructed with a titanium alloy substrate with Commercially pure titanium coating was developed to improve initial and long-term fixation. Radiosterometric analysis along with cadaveric testing have yielded minimal shell migration and satisfactory coefficient of friction, respectively. The purpose of this study was to evaluate long-term outcomes of this highly-porous titanium shell in primary total hip arthroplasty. Survivorship rates, functional outcomes, complications, 90-day readmissions, and radiographic outcomes at three-years postoperative were studied.

Methods: The database of primary cementless THAs were performed at 12 centers as a part of a prospective, non-randomized, post-market study. This yielded 255 cases in 250 patients (149 men, 101 women) who had a mean age of 63 years (31-84). Aseptic and all-cause Kaplan-Meier survivorship were calculated. The Harris Hip Score (HHS), Short Form 12 (SF12), Lower Extremity Activity Score (LEAS), EuroQol five dimensions questionnaire (EQ-5D), and radiographs were collected preoperatively and postoperatively at six weeks, one year, and three years. Surgical details were also collected. Effect size was analyzed according to Cohen's criteria to determine index responsiveness. Anteroposterior (AP) pelvis, AP femur, and lateral radiographs were reviewed by an independent surgeon.

Results: The aseptic survivorship was 99.6% (95% CI: 1.004 to 0.988). There was one case of peri-prosthetic femoral fracture at 5 weeks postoperative. The all-cause survivorship was 98% (95% CI: 0.984 to 0.999). There were three cases of deep joint infection at 2-weeks, 7-weeks, and 19-months postoperatively. The mean scores at three years postoperative were the following: HHS, 91.0 points (33.0-100.0); SF-12 physical score, 47.02 points (20.46-61.36), SF-12 mental score, 56.52 (27.50-67.91); LEAS,11 points (6.0-15.0), EQ-5D VAS score, 85 points (50-100), and the EQ-5D TTO, 0.90 points (0.71-1.00) (Table 1). There were five intraoperative complications, all unrelated to the device, and a 3.9% readmission rate within the 90-day period. Excluding patients who underwent revision, all implants were stable, and there were no progressive radiolucencies, loosening, or shielding of acetabular component noted. Furthermore, of the reviewed radiographs, there were no radiolucent line findings in all three acetabular zones at the 3-year window for the same subjects where findings in all three zones were prevalent at the 6-week and 1-year window (Figure 1).

Discussion: The highly porous acetabular shell investigated in this study demonstrated excellent aseptic and overall survivorship along with satisfactory functional outcomes at the minimum of 3 year follow-up after THA. Although five patients sustained intraoperative complications, four of them were related to the femoral component and were successfully treated intraoperatively. Radiographically, there were no failures, deemed by migration greater than 5mm in any direction or 2mm radiolucent lines all three acetabular zones. These results show promising results for this highly porous acetabular shell in THA. Longer-term follow-up is necessary to confirm continued excellent results of this implant.

Figures

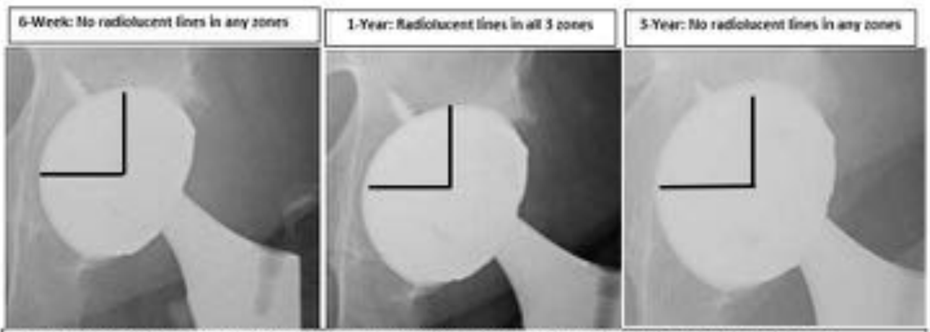

Figure 1: Digital radiographs demonstrating 'radiolucent lines' at the 1-year x-ray filling in by the 3-year x-ray.

Figure 1

	Preoperative	6-Week	1-Year	3-Year
HHS	50.59	79.4	91.44	90.89
LEAS	8.42	8.78	11.1	11.57
SF-12 Physical	29.58	40.55	48.23	47.02
SF-12 Mental	52.65	53.95	56.38	56.52
EQ-5D *Health State Over Time*	66.73	77.35	82.94	83.69
EQ-5D* *Time Trade Off*	0.57	0.81	0.89	0.88

Figure 2

#6126

Comparison of Total Hip Arthroplasty With and Without Computed Tomography-Based Navigation System for Osteonecrosis of the Femoral Head: A Propensity Score Matched Analysis

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Introduction: Several studies before 1990 showed that total hip arthroplasty (THA) for patients with osteonecrosis of the femoral head (ONFH) have poorer outcomes than for patients with osteoarthritis (OA) because patients with ONFH tend to be younger and more active, which are assumed to relate to higher dislocation and aseptic loosening rates observed in patients with ONFH. However, there have been many technological innovations in THA, including implant designs, liner materials, surgical techniques, and computer-assisted surgeries, and recent studies after 2000 demonstrated good outcomes of THA, even for patients with ONFH. Although several studies reported the usefulness of the computed tomography (CT)-based navigation system in THA, there have been no reports that compared the clinical and radiological outcomes of THA performed with or without a CT-based navigation system in patients with ONFH. Therefore, the purpose of this study is to investigate the clinical and radiological outcomes following navigated or non-navigated THA in patients with ONFH.

Methods: Between January 1990 and December 2014, 271 hips from 192 consecutive patients who underwent primary THA for ONFH with a follow-up period of longer than 2 years (mean, 10 years; range, 2–26 years) were included in this study. Of the 271 hips, THA was performed without a CT-based navigation system in 110 hips between January 1990 and February 2004 (non-navigation group), whereas 161 hips underwent THA with a CT-based navigation system (CT-Hip System, Stryker) between March 2004 and December 2014 (navigation group). Twenty-eight hips underwent THA through an anterolateral approach, 26 hips underwent THA on one side without CT-based navigation system and on the other side with CT-based navigation system, 17 hips underwent osteotomy before THA, and 13 hips underwent hip resurfacing or bipolar hip arthroplasty on the other side were excluded. We performed propensity score matching in relationship to sex, age at surgery, and body mass index in a 1:1 ratio for both groups (Fig. 1). Finally, 160 hips from 121 patients (80 hips of each group) were selected for this analysis (Table 1). We evaluated clinical and radiological outcomes, and also calculated the cup alignment observed in the early postoperative, anteroposterior radiographs.

Results: No significant difference was observed in clinical score between both groups. Dislocation was significantly lower in the navigation group (0 hips, 0%) than in the non-navigation group (eight hips, 10%; $p = 0.003$), whereas periprosthetic joint infection and aseptic loosening did not differ between both groups. Variance of cup alignment was lower in navigation group than in the navigation group ($p < 0.001$) (Fig. 2). Based on the results from the Cox proportional hazard model, the use of the CT-based navigation system (HR; 0.54, 95% CI, 0.35–0.84; $p = 0.007$), and a femoral head diameter ≥ 36 mm (HR; 0.47, 95% CI, 0.28–0.75; $p = 0.002$) turned out to be the predictors for preventing dislocation.

Conclusion: Use of the CT-based navigation system and large femoral head diameter are helpful for preventing dislocation in patients with ONFH.

Figures

Fig. 1 Flow diagram illustrating procedure for patient inclusion.

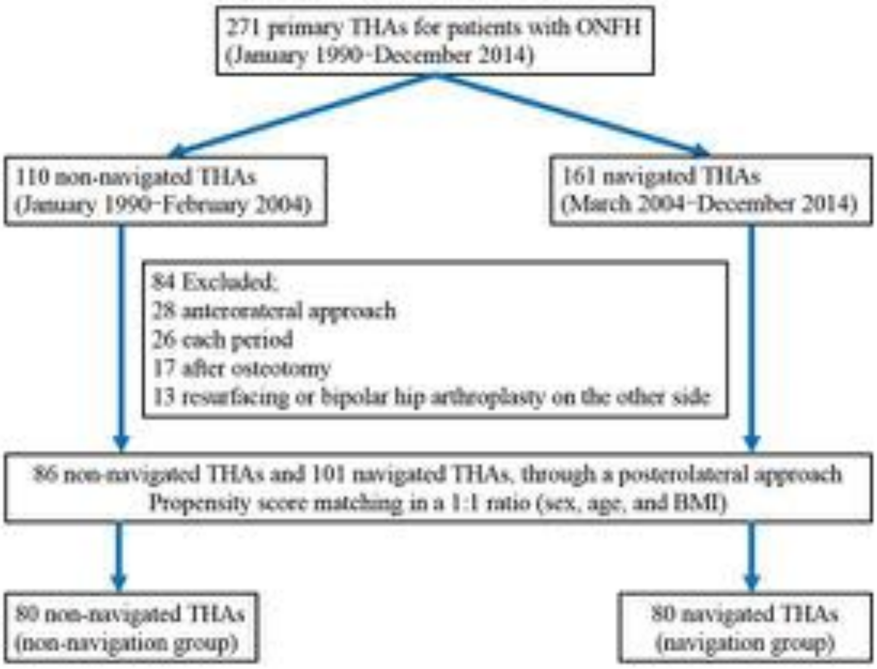

Figure 1

Table 1 Characteristics of patients after propensity score matching

Variable	Non-navigation group (80 hips)	Navigation group (80 hips)	p value
Age (years, mean ± SD)	48.5 ± 13.2	48.0 ± 15.6	0.820
BMI* (kg/m^2, mean ± SD)	22.7 ± 3.2	22.8 ± 3.9	0.939
Sex			0.631
Male (hips)	48	45	
Female (hips)	32	35	
Etiology			0.122
Idiopathic (hips)	8	4	
Steroid (hips)	47	59	
Alcohol (hips)	25	17	
JIC† stage			0.015
3A (hips)	29	13	
3B (hips)	26	32	
4 (hips)	25	25	
Follow-up period (years, mean ± SD)	16 ± 6	6 ± 3	< 0.001

* body mass index, † Japanese investigation committee

Figure 2

Fig. 2 Scattergram of the cup alignment plots of anteversion against inclination.

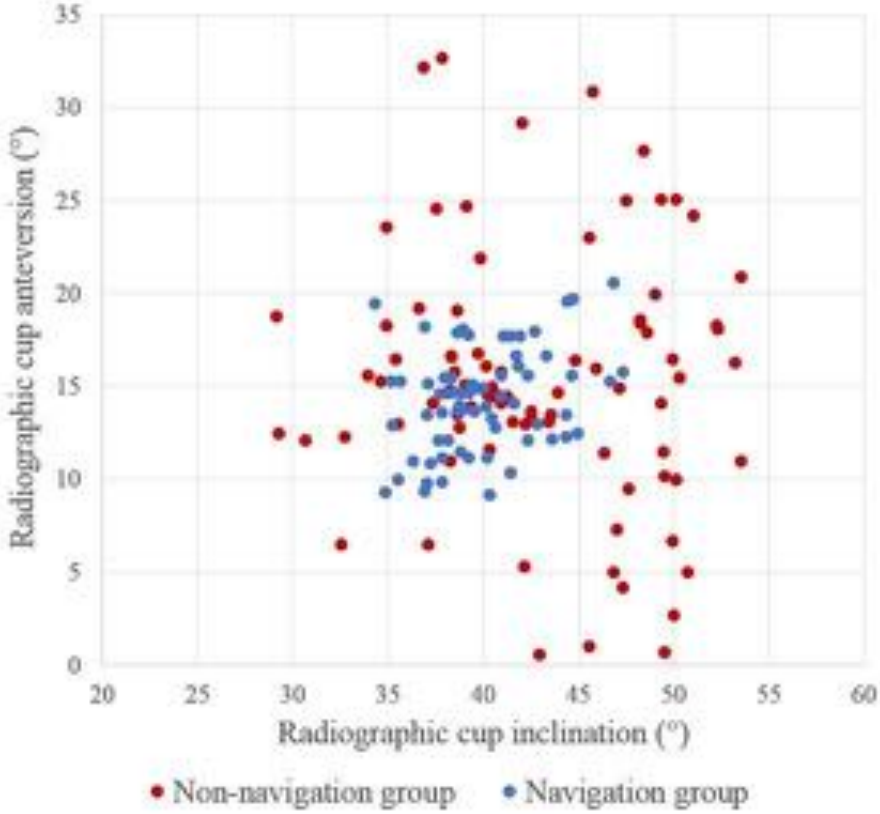

Figure 3

#6164

Total Hip Arthroplasty Utilizing an Uncemented, Flat, Tapered Stem With a Reduced Distal Profile

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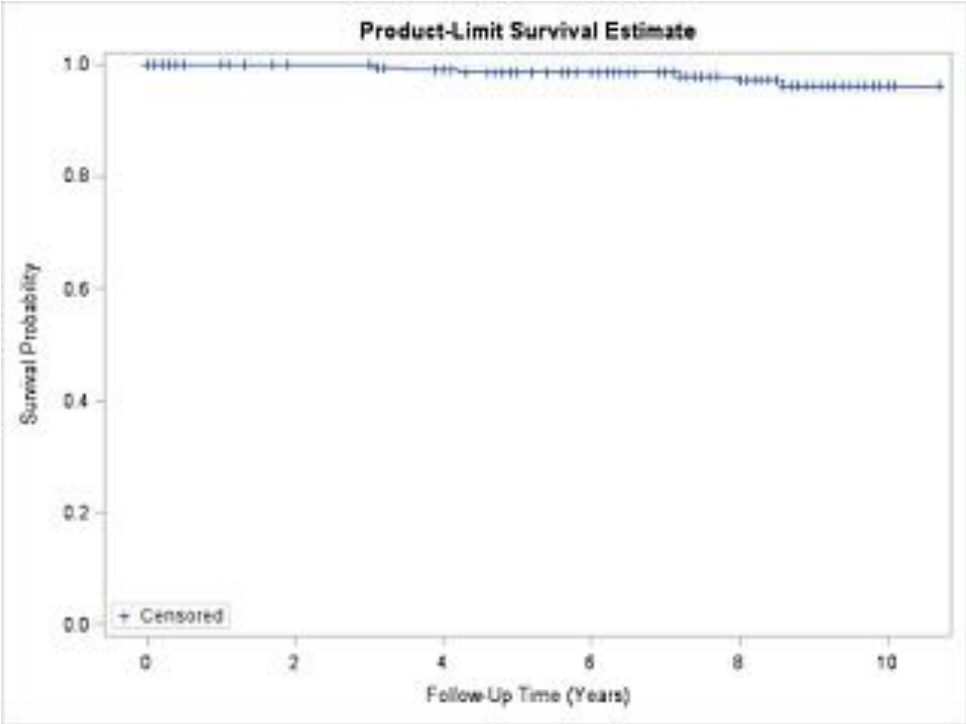
Introduction: Hip implants with decreased distal widths relative to proximal widths, ideally allows for maximum metaphyseal fit and as such can more closely match patients' femoral neck geometry and length. The aim of this retrospective study was to analyze the mid-term results of total hip arthroplasty (THA) utilizing a never before reported on uncemented, flat, tapered stem with a reduced distal profile in patients who had been followed for a minimum of five years.

Methods: Two hundred and twenty-eight consecutive THAs in 211 patients were performed between 2007 and 2009, by a single surgeon, utilizing a stem with a reduced distal profile (ANTHOLOGY, Smith&Nephew). Femoral and/or acetabular component revision was determined for all hips. Kaplan Meier was used to analyze implant survival.

Results: At a median of 8.4 (7.1 – 9.3) years there was 92% follow-up with 16 patients (18 hips) lost to follow-up. Six hips were revised, one femoral component revision for aseptic loosening, and the others acetabular revisions for instability (n=3), dislocation (n=1), squeaking (n=1). At 10.7 years Kaplan Meier curves were 96.3% for all-cause revision and 99% for femoral component revision only. Of the 22 patients (22 hips) who had died, all had retained their hips and died from co-morbidities.

Conclusions: Primary THA utilizing an uncemented, flat, tapered stem with a reduced distal profile had high implant survivorship at a minimum follow-up of 5 years.

Figures


Product-Limit Survival Estimate
1.0
0.8
0.6
0.4
0.2
0.0
Survival Probability
+ Censored
0
2
4
6
8
10
Follow-Up Time (Years)
Figure 1

Clinical Results of the Cemented THA Stem With Double-Tapered Design and Smooth Surfaced Titanium Alloy for More Than 10 Years

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[Introduction] We have investigated the long-term (minimum follow-up period; 10 years) clinical results of the total hip arthroplasty (THA) using K-MAX HS-3 tapered stem.

[Materials and Methods] In K-MAX HS-3 THA (Kyocera Medical, Kyoto, Japan), cemented titanium alloy stem and all polyethylene cemented socket are used. This stem has the double tapered symmetrical stem design, allowing the rotational stability and uniform stress distribution (Fig. 1). The features of this stem are; 1. Vanadium-free high-strength titanium alloy (Ti-15Mo-5Zr-3Al), 2. Double-tapered design, 3. Smooth surface (Ra 0.4µm), 4. Broad proximal profile, 5. Small collar. Previous type stem, which was made of the same smooth-surface titanium alloy, has the design with cylindrical stem tip, allowing the maximum filling of the femoral canal (Fig. 2). Osteolysis at the distal end of the stem had been reported in a few cases in previous type with cylindrical stem tip, probably due to the local stress concentration. Therefore the tapered stem was designed, expecting better clinical results.

157 THAs using HS-3 taper type stem were performed at Kitano Hospital between March 2004 and March 2008. And 101 THAs, followed for more than 10 years, were investigated (follow-up rate; 64.3%). The average age of the patients followed at the operation was 61.7 years and the average follow-up period was 10.9 years. The all-polyethylene socket was fixed by bone cement, and the femoral head material was CoCr (22mm; 5 hips, 26 mm; 96 hips).

[Results] Two hips were revised, one was due to late infection, and the other due to breakage of the implant in trauma. Japanese orthopaedic association (JOA) score improved from 40 to 86 points. Postoperative complication was three periprosthetic fractures (one femoral shaft fracture and two greater trochanteric fractures) and femoral shaft fracture case was operated. Dislocation was not observed. Socket loosening (Hodgkinson, Type 3, 4) and stem loosening (Harris, definite and probable) were not observed radiographically. Cortical hypertrophy was observed in 7.9%. The survival rate of HS-3 tapered stem was 98% for revision due to any reason and 100% for revision due to aseptic loosening.

[Discussion] The long-term clinical results of K-MAX HS-3 tapered stem were excellent. The osteolysis at the stem tip was not observed in this type, which was observed in a few cases in previous type. From the X-ray finding, it was suggested that this taperd stem had more uniform stress distribution to the femoral bone than previous type. Moreover, the problems associated with titanium alloy usage were not observed.

From the present investigation, good farther long-term results of the tapered titanium stem were expected.

Figures

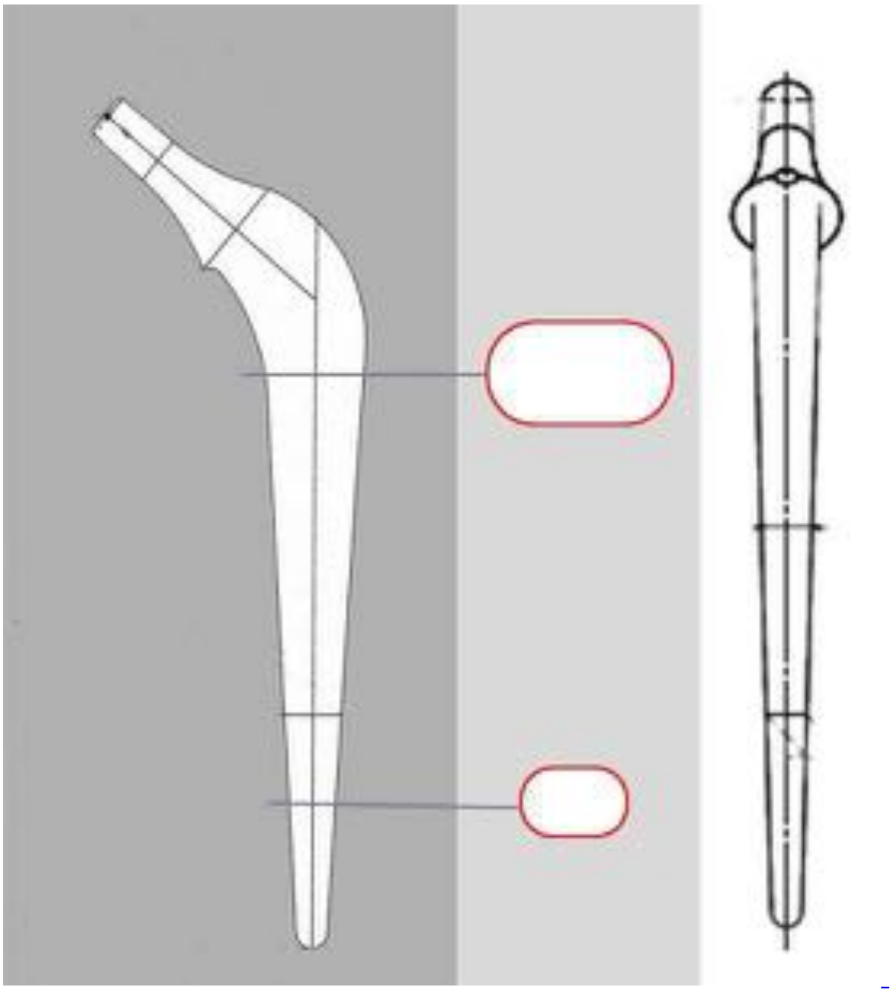

Figure 1

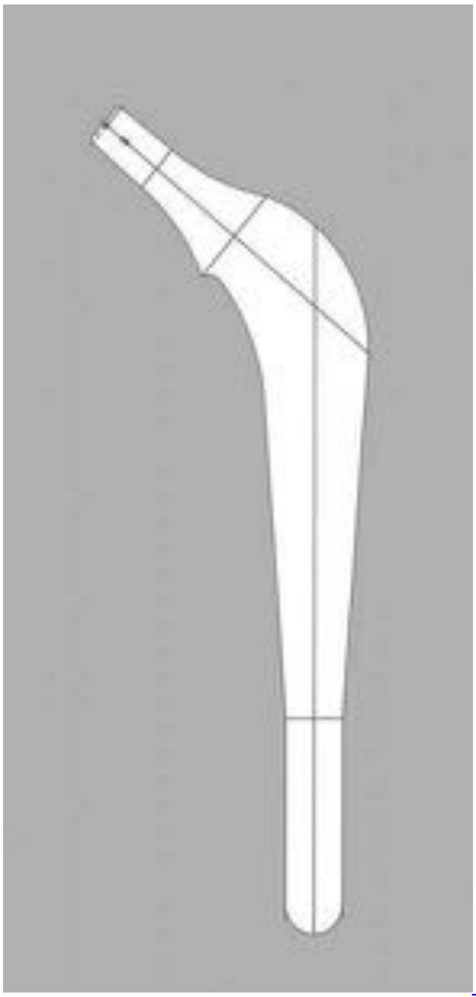

Figure 2

#5833

Early Clinical Outcomes of a Tapered Wedge Femoral Hip Stem

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INTRODUCTION

Wedge femoral stems used in total hip arthroplasty (THA) have evolved with modifications including shorter lengths, reduced distal geometries, and modular necks. Unlike fit and fill stems which contact most of the metaphysis, tapered wedge femoral stems are designed to achieve proximal medial/lateral fixation. These single taper, wedge stems have demonstrated positive clinical outcomes. The tapered wedge stem evaluated in this study has further reduced distal geometry to provide a wedge-fit within the metaphysis of the proximal femoral canal for all femur types (Dorr A, B, C). The objective of this study was to evaluate the early clinical outcomes, including femoral stem subsidence, of a tapered wedge femoral stem (Figure 1).

METHODS

Fifty subjects (28 males, 22 females; mean age: 64.7±9.7 years; mean BMI: 29.6±4.6) underwent primary THA with a tapered wedge femoral stem. IRB approval was received prior to conducting the study and all participants signed the informed consent. Clinical data outcomes for this study included the Harris Hip Score (HHS), the Oxford Hip Score (OHS), revisions, and subsidence at the 6-week, 3-month, 1-year, and 2-year post-operative time points. Femoral stem subsidence was measured by an independent third party. Student t-tests were used to identify significant mean differences between genders ($p<0.05$).

RESULTS

The means and standard deviations for the HHS and OHS are shown in Figure 2. For patients returning for their 2-year post-operative visit (n=42), the HHS improved by 40.7 points to 91.9 from 51.2 and the OHS improved by 23.5 points to 44.6 from 21.1. There was no significant difference between genders with regard to age, BMI, or HHS scores. However, the males had significantly higher pre-operative OHS scores (23.4 vs. 18.2) and 3-month post-operative OHS scores (43.7 vs. 40.3). There were no revisions. There were no observations of femoral stem subsidence at 1 year (n=45) or 2 years (n=40).

DISCUSSION

The tapered wedge femoral stem exhibited positive early clinical results as demonstrated by the significant improvement in functional outcome scores from the pre-operative visit to 2-years post-operative. These 2-year improvements are better than moderate clinically important improvements reported in the literature (40.1 points for HHS).[1] Functional outcomes scores continued to improve at the 6-week, 3-month, and 1-year post-operative visits. The 1-year and 2-year outcomes were not significantly different. Additionally, the implant was well fixated as there were no reports of femoral stem subsidence 2 years post-operative.

SIGNIFICANCE

The tapered wedge femoral stem evaluated in this study demonstrated positive early clinical performance with no reports of femoral stem subsidence or revisions. This tapered wedge stem design is a promising alternative to conventional femoral stems.

REFERENCES

1. Singh, Schleck, Harmsen, & Lewallen. Clinically important improvement thresholds for Harris Hip Score and its ability to predict revision risk after primary total hip arthroplasty. BMC Musculoskelet. Disord. 17, (2016).

Figures


Figure 1. Tapered Wedge Femoral Stem.

Figure 1

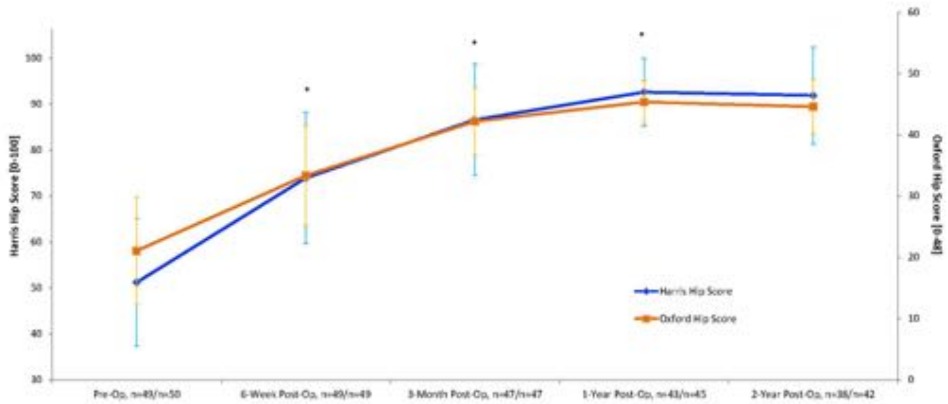

Figure 2. Clinical Outcome Scores. Data represent means +/- standard deviation. n=HSS count/OHS count.
* indicates significant difference from the previous time point (p<0.05).

Figure 2

#6150

Radiographic Change Around the Standard Tapered Round Stem and the Shorter Tapered Round Stem Two Years After Total Hip Arthroplasty

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INTRODUCTION: Recently, short shaped stem becomes popular in total hip arthroplasty (THA). Advantages of the short stem are preserving femoral bone stock, thought to be less thigh pain, suitable for minimally invasive THA. However, bony reaction around the short stem has not been well known. The purpose of this study was to compare the two years difference of radiographic change around the standard tapered round stem with the shorter tapered round stem.

MATERIALS AND METHODS: Evaluation was performed in 96 patients (100 joints) who underwent primary THA. Standard tapered round stem (Bicontact D stem) was used in 44 patients from January 2011 to May 2013. Shorter stem (Bicontact E stem) was used in 56 patients from May 2015 to March 2016. The proximal shapes of these two stems are almost the same curvature. The mean age at surgery was 64 years. The mean BMI at surgery was 24.0 kg/m^2. Eighty-six patients had osteoarthrosis and 10 patients had osteonecrosis. Evaluation was performed 2 years after surgery with standard AP radiographs. The OrthoPilot imageless navigation system was used during surgery. Evaluation of the stem fixation, stress shielding, and cortical hypertrophy were carried out.

RESULTS: There were no differences of patient characteristics between the standard D stem group and the shorter E stem group. All 100 stems showed bony stable fixation two years after surgery. No subsidence was observed in both groups. No clear zone was observed around the stems in both groups. Cortical hypertrophy was observed 19 patients (43.2%) with the standard D stem group and 13 patients (23.2%) with the shorter E stem group. The standard D stem group showed higher incidence of cortical hypertrophy. Stress shielding was observed 35 patients (80%) with the standard D stem group and 42 patients (75%) with the shorter E stem group. The number of grade 1 and grade 2 stress shielding cases were 13 and 22 with the standard D stem group and 10 and 32 with the shorter E stem group, respectively. There were no grade 3 stress shielding case in both groups. Regarding the incidence of stress shielding, there was no difference between the two groups.

DISCUSSION: This study demonstrated that the shorter stem showed less incidence of cortical hypertrophy compared to the standard stem. With radiographic evaluation, both standard and shorter stem showed good fixation. The meaning of cortical hypertrophy, whether it is a good reaction for the femur or not, has not been clarified yet. Less bony reaction around the shorter stem may suggest the potential for better clinical performance of the shorter stem compare to the standard stem.

#5811

Learning Curve for Direct Anterior Approach for Total Hip Arthroplasty

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INTRODUCTION

The direct anterior approach (DAA) for total hip arthroplasty has become a popular technique. Proponents of the anterior approach cite advantages such as less muscle damage, lower dislocation risk, faster recovery, and more accurate implant placement for the approach. However, there is a steep, complex learning curve associated with the technique. The present study seeks to define the learning curve based on individual surgical and outcome variables for a high-volume surgeon.

METHODS

300 consecutive patients were retrospectively analyzed. Intraoperative outcomes measured include surgery time and estimated blood loss (EBL). Complications include intraoperative fracture, post-operative fracture, infection, dislocation, leg length discrepancy, loosening, and medical complications such as deep vein thrombosis (DVT) and pulmonary embolism (PE). Segmented regression models were used to elucidate the presence of a learning curve and mastery of the procedure with regard to each individual variable.

RESULTS

The mean operative time was 77.1 minutes (range 40-213). Operative time improved at a rate of 6.6 minutes per case for the first 15 cases then by an average of 5 seconds per subsequent case. The mean EBL for the series was 288.6 mL. Segmented regression shows EBL decreased at a rapid rate until case 52, followed by a more gradual decline. Complications were higher in the first 7 surgeries, with a 48% decrease in the likelihood of complication with each subsequent surgery. The improvement continued through the rest of the series with a 0.5% decrease in likelihood with each surgery.

DISCUSSION

Our data contributes to the current body of literature by defining the learning curve with what we consider the most pertinent outcomes. First, we show that operative efficiency can be gained quite quickly (15 cases) while the slower improvement in EBL demonstrates continued learning about the anatomy. Our data is consistent with previous published reports regarding complication improvement. The present study will provide surgeons considering DAA useful information regarding what to expect during their learning curve. Furthermore, the data can be useful for surgeons charged with teaching the technique to critically evaluate what learning curve variables can be improved to hasten the learning curve.

Figures

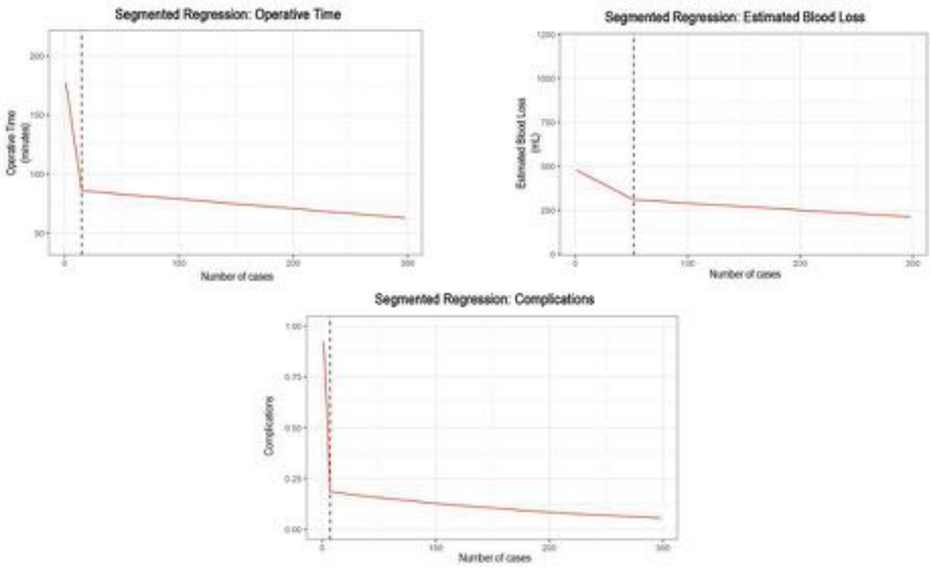

Figure 1

#5894

Early Outcomes of Obese Patients Undergoing Total Hip Arthroplasty: Comparison of Anterior to Posterior Approach

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ABSTRACT

BACKGROUND

The obesity crisis in the United States has caused a significant increase of hip arthritis. Surgical complication rates are higher in this population and guidelines are being used to select patients who are acceptable candidates for surgical intervention. This retrospective study evaluated the complication rates for obese patients undergoing total hip replacement compared to non-obese patients as defined by the World Health Organization (WHO). Additionally, we compared complication rates of the direct anterior approach (ATHA) versus the posterior approach (PTHA) in a consecutive group of patients using similar protocols.

METHODS

This study is an IRB approved retrospective review of 210 patients undergoing ATHA and 201 patients undergoing PTHA during the same time period by 2 experienced, high-volume total joint surgeons. Non-obese patients were compared to obese patients using WHO body mass index (BMI) classification. Minor and major complications were reviewed as well as surgical time, length of stay, disposition, and short-term outcome measures (including pain scores, narcotic use, and assistive device use).

RESULTS

The non-obese cohort (BMI < 30) had lower complication rates (2.8% major, 4.4% minor) when compared to the obese cohort (8.7% major, 9.9% minor). Major complications by obese class were as follows: Class I 8.6%, Class II 7.1% and Class III 11.5%. The non-obese ATHA cohort had lower complication rates (0.8% major, 5.0% minor) compared to the PTHA cohort (5.0% major, 6.7% minor). Obese patients had 6.3% major and 9.9% minor complication rates in ATHA, compared to 11.1% major and 10.0% minor complication rates in PTHA. Lastly, the evaluation of short term outcomes showed more favorable results for ATHA compared to PTHA for both obese and non-obese patients.

CONCLUSION

Obesity was associated with an increased risk of complications and less favorable short-term outcomes following THA. Direct anterior THA was also associated with lower complication rates and more favorable short-term outcomes.

#6074

Acetabular Reaming Accuracy: Optimal Techniques and Single-Use Reamers

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Aims

Accurate and precise acetabular reaming is a requirement for the press-fit stability of cementless acetabular hip replacement components. The accuracy of reaming depends on the reamer, the reaming technique and the bone quality. Conventional reamers wear with use resulting in inaccurate reaming diameters, whilst the theoretical beneficial effect of ‘whirlwind’ reaming over straight reaming has not previously been documented. Our aim was to compare the accuracy and precision of single use additively-manufactured reamers with new conventional reamers and to compare the effect of different acetabular reaming techniques.

Materials and Methods

Forty composite bone models, half high-density and half low-density, were reamed with a new 61 mm conventional acetabular reamer using either straight or ‘whirlwind’ reaming techniques. This was repeated with a 61 mm single use additively-manufactured reamer. Reamed cavities were scanned using a 3D laser scanner with mean diameters of reamed cavities compared using the Mann-Whitney U test to determine any statistically significant differences between groups ($p<0.05$) [Fig. 1].

Results

Reaming errors were significantly higher in low-density bone compared to high-density bone for both reamer types and reaming techniques tested (61.9 mm (SD 0.7) vs 61.4 mm (SD 0.4), respectively; $p=0.0045$). Whirlwind reaming was significantly more accurate and precise than straight reaming using both conventional (61.3 mm (SD 0.1) vs 62.3 mm (SD 0.4), respectively; $p<0.0001$) and single use reamers (61.1 mm (SD 0.3) vs 61.7 mm (SD 0.7), respectively; $p=0.0058$) [Fig. 2]. The novel single use reamer was significantly more accurate than the unused conventional reamer, using both the straight (61.7 mm (SD 0.7) vs 62.4 mm (SD 0.4), respectively; $p=0.0011$) and whirlwind techniques (61.2 mm (SD 0.3) vs 61.3 mm (SD 0.1), respectively; $p=0.0002$) [Fig. 3].

Conclusion

This is the first study to our knowledge that has assessed acetabular reaming technique in both low and high density saw bones. Improved reaming accuracy and precision was seen in both devices tested when using the ‘whirlwind’ technique in both high-density and low-density bone models when compared to a straight reaming technique. The single use device assessed reamed a cavity size closer to its stated size (61mm) compared to conventional reamers. Based on this study we suggest using a careful “whirlwind” technique when performing acetabular reaming, and for the surgeon to pay particular attention when performing joint replacement in patients with reduced bone quality as there is likely to be more variability in acetabular reaming accuracy in these patients.

Figures

Fig 1. Example of a laser scanned reamed foam block cavity used to determine mean diameter of reamed cavity.

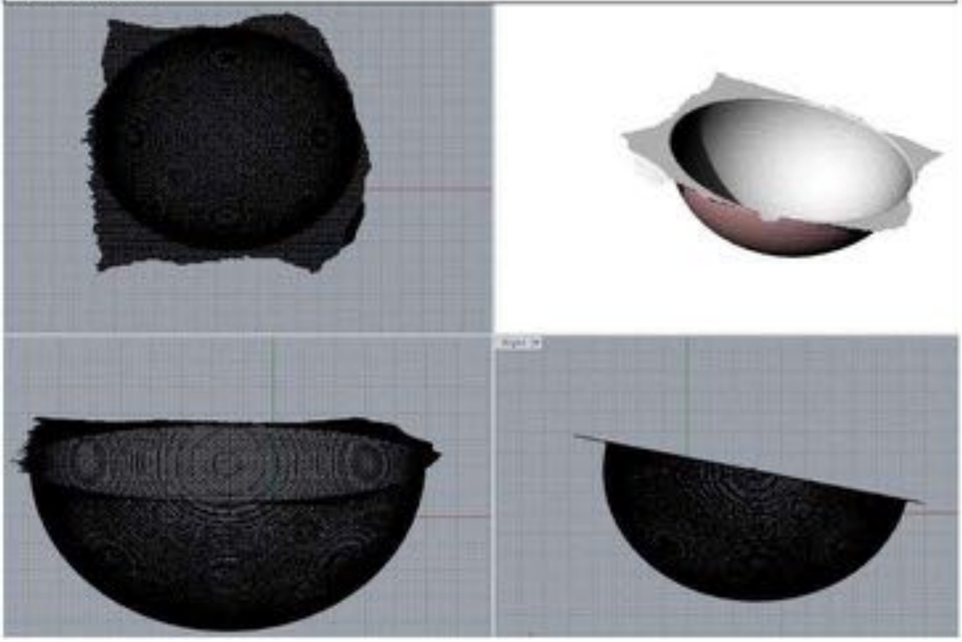


Figure 1

Fig 2. Bar graph comparing the mean differences in actual vs expected cavity diameters, with standard deviations (SD), of different test groups. (HD = high density, LD = low density)

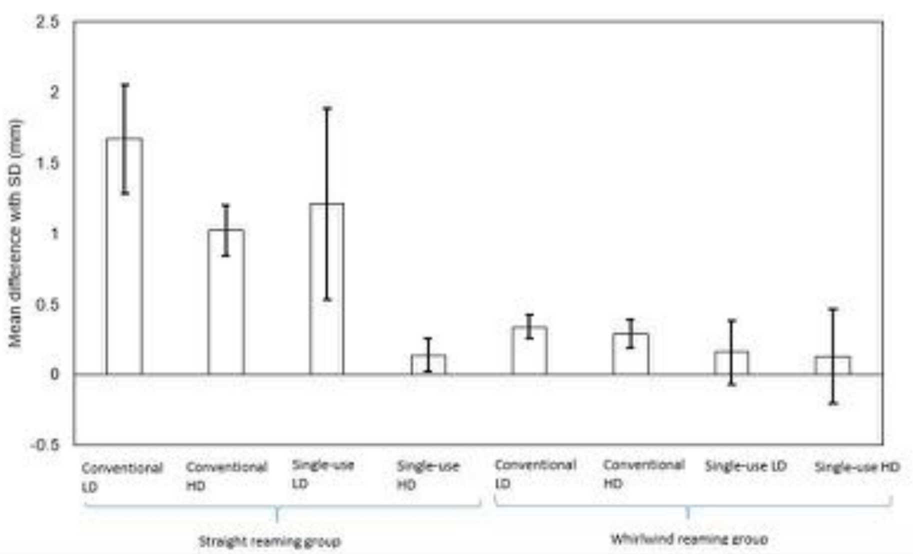
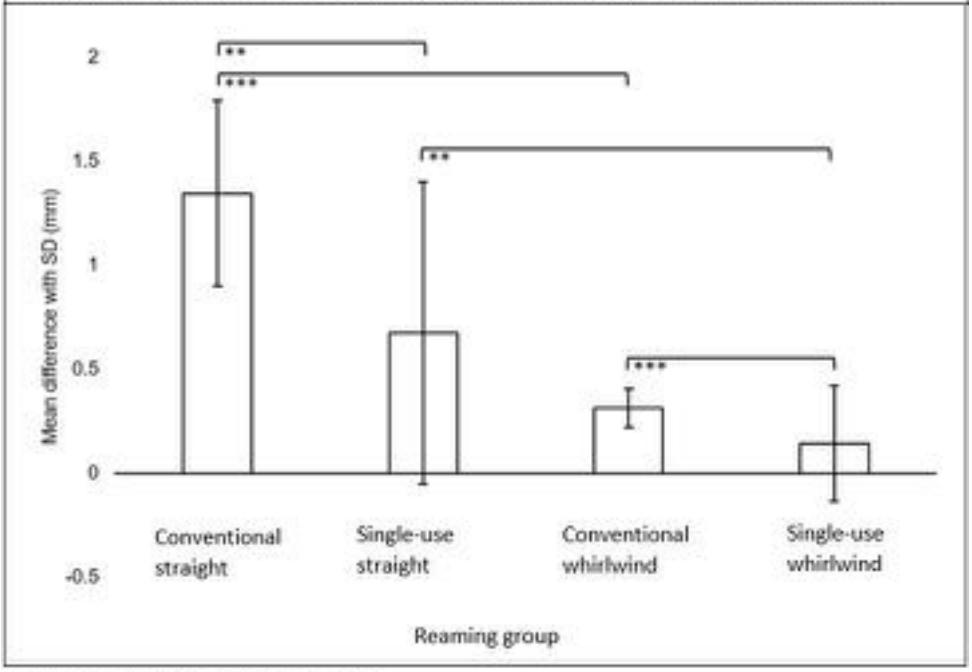


Figure 2

Fig 3. Bar graph comparing mean differences in actual vs expected cavity diameters and standard deviations for conventional and single use reamers using straight and whirlwind techniques.



Asterisks indicate pairwise significance at
* p < 0.050
** p < 0.010
*** p < 0.001

Figure 3

Smart Hand-Held Imageless Navigation for Augmented Surgical Quality and Improved Patient Safety in Total Hip Arthroplasty

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Introduction: Computer navigation is a highly sophisticated tool in orthopedic surgery for component placement in total hip arthroplasty (THA). A number of recommendations have been published. Although Lewinnek's safe-zone is the best-known among these its significance is questioned in recent years since it addresses the acetabular socket only and ignores the femoral stem. Modern target definitions consider both socket and stem and provide well-defined recommendations for complementary component positioning. We present a new small-sized hand-held imageless navigation system that implies these targets and supports the surgeon in realizing the concept of combined anteversion and combined Safe-Zone (cSafe-Zone) in THA and to control leg length and offset without altering the standard surgical work-flow and we report initial results. **Methods:** The targets for positioning the components of a total hip as expressed by cup inclination (cIncl) and anteversion (cAV), stem antetorsion (sAT) and neck-to-shaft angle (sNSA) are determined for a specific prosthesis system using a computerized 3D-model. The optimizing goal in this concept is maximizing the size of the cSafe-Zone providing the largest target zone for an impingement-free prosthetic range of motion (ROM) in order to minimize the risk for dislocation for movements in physiologic planes and combined movements. Independent parameters like head size, head-to-neck ration and also component orientations like cIncl, cAV, sAT and sNSA were varied systematically and the optimal cSafe-Zone was computed in semi-automated batch runs. These optimized prosthesis-specific results were introduced into the software of the hand-held navigation system. Additionally, the system measures leg length, offset, acetabular and femoral head centers pre- and postoperatively. **Results:** The outline of the cSafe-Zone is not rectangular like Lewinnek's recommendation but polygonal and its size shows prosthesis-specific maxima. The largest zones are found for optimal sNSA values at 126° +/-4°, optimal ranges for cIncl depend on head size and range from 44° to 36°, best sAT range from 10° to 16°, cAV from 18° to 25°. There is a prosthesis-specific linear correlation between sAT and cAV that denotes the combined anteversion and also its target value. The target value for combined anteversion is not dependent on pelvic inclination. The hand-held navigation system displays all these orienting parameters as well as leg-length and offsets. Furthermore, it supports a virtual reduction work-flow thus accelerating surgery. All these information provide important decision-making details for the surgeon intraoperatively in real-time for augmented quality.

Conclusion: The combined Safe-Zone provides the basis for patient- and implant-specific control of prosthesis implantation. It includes all important positioning parameters of both total hip components and such gives well-defined individual recommendations for the targets. The new hand-held navigation system provides a smart way to direct and control the total hip implantation according to the best combined orientation considering also the concept of combined Safe-Zone. Such it prevents outliers, provides better safety and documents the surgical workflow and the final result of the surgery.

Figures

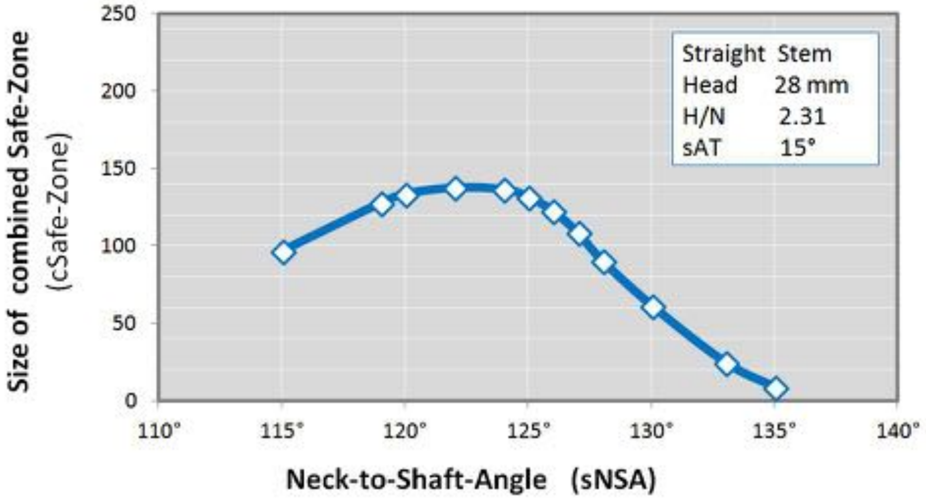

Fig. 1 The size of the combined Safe-Zone (cSafe-Zone) is dependent on the Neck-to-Shaft-Angle (sNSA). Stems with sNSA between 120° and 125° are optimal. Stems with sNSA higher than 135° should not be used in combination with 28mm heads.

Figure 1

Improved Accuracy in Restoration of Native Hip Biomechanics in Robotic-Arm Assisted Surgery Compared to Conventional Manual Techniques for Total Hip Arthroplasty: A Prospective Cohort Study

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Objectives:

Robotic assisted surgery aims to reduce surgical errors in implant positioning and better restore native hip biomechanics compared to conventional techniques for total hip arthroplasty (THA). The primary objective of this study was to compare accuracy in restoring the native centre of hip rotation in patients undergoing conventional manual THA versus robotic-arm assisted THA. Secondary objectives were to determine differences between these treatment techniques for THA in achieving the planned combined offset, cup inclination, cup version, and leg-length correction.

Methods:

This prospective cohort study included 50 patients undergoing conventional manual THA and 25 patients receiving robotic-arm assisted THA. All operative procedures were undertaken by a single surgeon using the minimally-invasive posterior approach. Two independent blinded observers recoded all radiological outcomes of interest using plain radiographs. Patients in both treatment groups were well-matched for age, gender, body mass index, laterality of surgery, and ASA scores.

Results:

Interclass correlation coefficient was 0.92 (95% CI: 0.84 - 0.95) for intra-observer agreement and 0.88 (95% CI: 0.82-0.94) for inter-observer agreement in all study outcomes. Robotic THA was associated with improved accuracy in restoring the native horizontal ($p<0.001$) and vertical ($p<0.001$) centres of rotation, and improved preservation of the patient’s native combined offset ($P<0.001$) compared to conventional THA. Robotic THA improved accuracy in positioning of the acetabular cup within the combined safe zones of inclination and anteversion described by Lewinnek et al ($p=0.02$) and Callanan et al ($p=0.01$) compared to conventional THA (figures 1-2). There was no difference between the two treatment groups in achieving the planned leg-length correction ($p=0.10$).

Conclusion:

Robotic-arm assisted THA was associated with improved accuracy in restoring the native centre of rotation, better preservation of the combined offset, and more precise acetabular cup positioning within the safe zones of inclination and anteversion compared to conventional manual THA.

Clinical relevance:

Robotic-arm assisted THA enables improved preservation of native hip biomechanics compared to conventional manual THA.

Figures

Figure 1: Accuracy of cup positioning within Lewinnek's (A + B) and Callanan's (A) safe zones in patients undergoing conventional manual THA

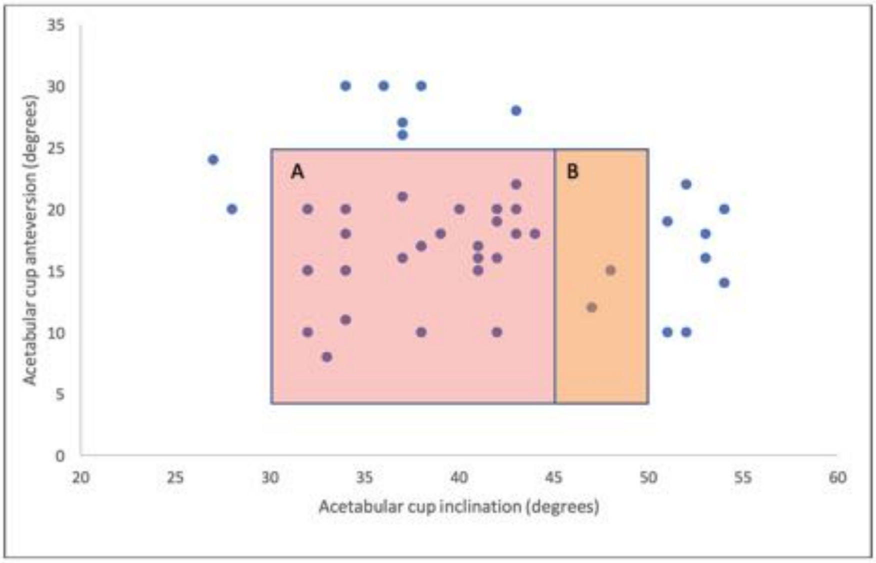

Figure 1

Figure 2: Accuracy of cup positioning within Lewinnek's (A+B) and Callanan's (A) safe zones in patients undergoing robotic-arm assisted THA

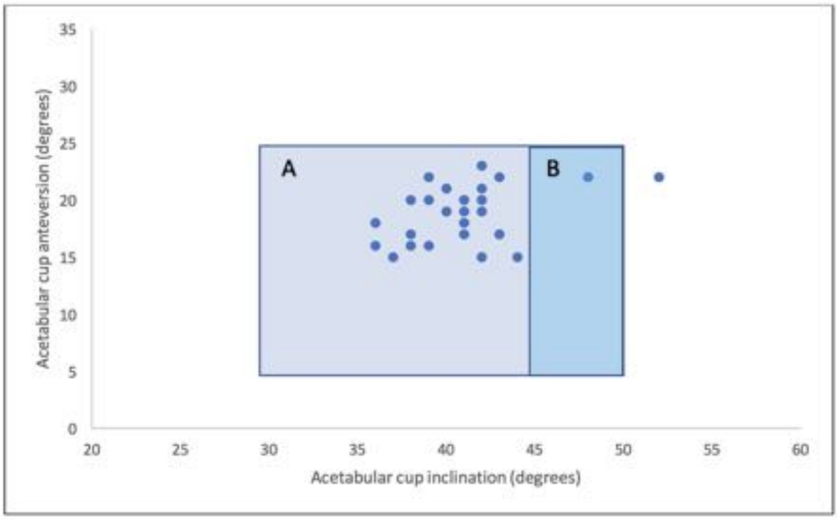

Figure 2

#5792

Using an Active Robotic System for THA - a Benefit or Only Cost Intensive Technology ?

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BACKGROUND:

The most important precondition for the durability of an implant is a primary stability. The surgical technique is a major factor for long-lasting stability. Conventional techniques show possible intra- and postoperative problems. Using an Active Robotic System can reduce/avoid these problems.

Manual technique shows following problems: No (or bad) preoperative planning, malposition of the stem (varus/valgus/rotation) and cup (anteversion/inclination), incorrect implant size, intraoperative fracture/fissure, dislocation/luxation, subsidence of the implant after weightbearing or leg length difference (LLD). To avoid or reduce these complications we used in more than 6500 cases such an Active Robotic System instead of conventional (manual) methos.

METHOD:

To avoid/reduce these surgical problems and get more accuracy and precision we used over 10 years an Active Robotic System (ROBOC/Think Surgical solution one).

The system consists of 2 innovative technologies:

1. T-PLAN: a 3 D preoperative planning workstation

2. T-CAT: an active computer assisted tool - Robot

First step is a patient's CT scan of femur and pelvis. This information will be loaded into the T-PLAN. Using the workstation tool for all legally marketed implants (open platform), enables to explore several plan options, move and rotate implant's position (stem and cup), change size and even type of prostheses. Than the planned datas will be loaded into T-CAT. Cadaver tests complete clinical results.

FINDINGS:

During 10 years we used such a computer assisted active robot for more than 6500 cases. We compairedthe intra- and postoperative complications of 5000 (robotic) with 500 conventional treated patients. After a training curve we used this technology for all cementless impacted prosthesis with better results in comparison to manual method. E.g. reduction of luxation/dislocation (from 2.9% to 1.2%), postoperative subsidence (5.1% to 0.7%), fracture/fissure intraoperative (3.6% to 0.0%), malposition(14.6% to 0.2%), LLD (15.3% to 3.7%).

Cadaver tests showed a bone/implant contact of 95% using this new technology in comparison to manual reaming of only 35%. In all the years the further developments of the system showedgreat improvements. Regular incision and the operation time is not more than 15-20 minutes including system fixation, registration and cutting time. Multiple cadaver tests for cup position (inclination/anteversion) showed an extreme high accuracy to the preoperative planning (difference less than 3 degree).

CONCLUSION:

To reduce/avoid intra- and postoperative complications we used an Active Computer

Assisted Tool (active robotic system). After a training curve the results showed great benefits for patients, surgeons and hospitals.We used long and short stems and widened the applications for trauma and revision cases. The cost for investment is not low and there are also costs per case (disposables). But nevertheless of all different obstacles: There is a great benefit using an Active Computer Assisted Tool as a Surgical Robot!

#5701

Accuracy of Image-Less Navigation for Functional Cup Positioning in Total Hip Arthroplasty

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Introduction: Malpositioning of the acetabular cup component during total hip arthroplasty (THA) can be associated with significant post-operative complications including dislocation, impingement, increased wear rates. Computer-assisted navigation has the potential to improve the accuracy of cup positioning during THA. The purpose of this study was to compare acetabular cup position and post-operative leg length discrepancy (LLD) in patients who underwent primary THA using posterior approach.

Methods: Between August 2016 to October 2017, all THA with (n=79) or without (n=93) the assistance of an imageless navigation device (Intellijoint HIP®) were analyzed. Post-operative weight-bearing radiographs were analyzed using TraumaCad (version 2.5) for anteversion, inclination and LLD. Goal for cup placement was functional 40° inclination and 20° anteversion. Functional LLD was measured as compared to pre-operative radiographs and compared to contralateral side. Proportion of cups within Lewinnek's safe zone, proximity to a pre-operative target of and the LLD >5 mm was assessed.

Results: The mean age was 54.9 ±9.6 years (30 – 72) and 57.6 ±12.5 years (20 – 85) in control and navigated groups, respectively. Mean orientation in the navigated group was 20.6°± 3.3° (17 - 25) of anteversion and 41.9°± 4.8° (30 - 51) of inclination, vs. 25.0°± 11.1° (10 - 31) and 45.7°± 8.7° (29 – 55) in control group, where were statistically significant (p=0.005 and p=0.0), respectively. In the navigated group, significantly more acetabular cups were placed within Lewinnek's safe zone (anteversion: 78% vs. 47%, p=0.005; inclination: 92% vs. 67%, p=0.002). There was no significant difference in mean LLD in navigation and control groups (3.1 ± 1.5 mm vs. 4.6 ± 3.4mm, p=0.36), although fewer LLDs >5 mm was reported in the navigated group (7.1%) than in controls (31.4%, p=0.09).

Conclusion: The use of image-less computer-assisted navigation improved the accuracy of functional acetabular cup components were placed and may represent an important method for limiting post-operative complications related to cup malpositioning.

#5600

Navigation Improves the Survival Rate of Mobile Bearing Total Knee Arthroplasty by Severe Pre-Operative Coronal Deformation

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INTRODUCTION

Total knee arthroplasty (TKA) is a highly successful procedure. Restoring the limb alignment with an optimal ligament balance is considered critical, but to achieve both goals by cases with severe coronal deformation may be challenging. Various methods have been described to treat major varus deformities, but there has so far been no consensus on the type of prosthesis to use, or the preferred ligament balancing technique. Computer navigation for TKA may help improving prosthesis alignment especially in cases with severe coronal deformation.

The primary hypothesis of this study was that the 10 year survival rate of navigated TKAs for severe coronal deformation will be improved in comparison to conventional TKAs.

METHODS

All patients operated on between 2001 and 2004 in all participating centers for implantation of a TKA (whatever design used) were eligible for this study. Usual demographic and peri-operative items have been recorded. All patients were contacted after the 10 year follow-up for repeat clinical and radiological examination. Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information about prosthesis survival. Conventional and navigated TKAs were paired according to age, gender, body mass index and severity of the coronal deformation (with steps of 5°). Survival curve was plotted according to the actuarial technique, using the revision for mechanical reason as end-point. The influence of the implantation technique was assessed with a logrank test at a 0.05 level of significance.

RESULTS

1,604 TKAs were implanted during the study time-frame. 658 cases could be paired in conventional (329 cases) and navigated (329 cases) groups: in each group, 277 cases with a coronal deformation less than 10° and 52 cases with a coronal deformation over 10°. There was no difference in any baseline criteria between conventional and navigated TKAs. 118 patients deceased before the 10 year follow up (18%). Final follow-up was obtained for 382 cases (58%). 15 prosthetic revisions were performed for mechanical reasons during the follow-up time (2%). The global survival rate after 13 years was 97%. There was no significant difference between the 12 year survival rates of conventional (97%) and navigated (98%) TKAs in cases without severe coronal deformation. There was a significant difference between the survival rates of conventional (93%) and navigated (98%) TKAs in cases with severe coronal deformation.

DISCUSSION

This study confirms our initial hypothesis: navigated TKAs experienced a small but significant better long term survival after 12 years in comparison to conventional TKAs when a severe pre-operative coronal deformation was present, while no difference was observed in the opposite situation. A more consistent anatomical reconstruction and ligamentous balance of the knee with severe coronal deformation might be the explanation for this more consistent survival of the TKA in these challenging cases, while an optimal reconstruction is more consistently obtained with conventional implantation technique for less severe deformation.

This study suggests that navigation implantation should be the default technique for pre-operative coronal deformation greater than 10°.

Sensor-Driven Evaluation of Tibial Coronal Alignment: A Validation Study

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Introduction and Aims: Sensor technology is seeing increased utility in joint arthroplasty, guiding surgeons in assessing the soft tissue envelope intra-operatively (OrthoSensor, FL, USA). Meanwhile, surgical navigation systems are also transforming, with the recent introduction of inertial measurement unit (IMU) based systems no longer requiring optical trackers and infrared camera systems in the operating room (i.e. OrthAlign, CA, USA). Both approaches have now been combined by embedding an IMU into an intercompartmental load sensor. As a result, the alignment of the tibial varus/valgus cut is now measured concurrently with the mediolateral tibiofemoral contact load magnitudes and locations. The wireless sensor is geometrically identical to the tibial insert trial and is placed on the tibial cutting plane after completing the proximal tibial cut. Subsequently, the knee is moved through a simple calibration maneuver, rotating the tibia around the heel. As a result, the sensor provides a direct assessment of the obtained tibial varus/valgus alignment. This study presents the validation of this measurement.

Method: In an in-vitro setting, sensor-based alignment measurements were repeated for several simulated conditions. First, the tibia was cut in near-neutral alignment as guided by a traditional, marker-based surgical navigation system (Stryker, MI, USA). Subsequently, the sensor was inserted and a minimum of five repeated sensor measurements were performed. Following these measurements, a 3D printed shim was inserted between the sensor and the tibial cutting plane, introducing an additional 2 or 4 degrees of varus or valgus, with the measurements then being repeated. Again, for each condition, a minimum of five sensor measurements were performed. Following completion of the tests, a computed tomography (CT) scan of the tibia was obtained and reconstructed using open source software (3DSlicer).

Results: By identifying anatomic landmarks on the 3D reconstructed tibia and fibula, the actual tibial coronal alignment of 0.43° valgus was obtained (Figure 1a), in close agreement with the one degree valgus alignment reported by the optical navigation system. Both reference values match well with the 1.16° valgus (SD: 0.91°) calculated by the IMU- based sensor system. When introducing the shims, the sensor consistently predicts the relative angular changes, with a maximum relative difference between the expected and measured condition of 1.29°. For each condition, the standard deviation remained small, with values ranging from 0.27° to 0.60° based on at least five repeated measures (Figure 1b).

Conclusion: In conclusion, this paper demonstrates that sensor technology can be used to evaluate tibial coronal alignment, with an accuracy in line with available 3D measurement systems. The authors recognize however the need for further validation, currently being undertaken.

Figures

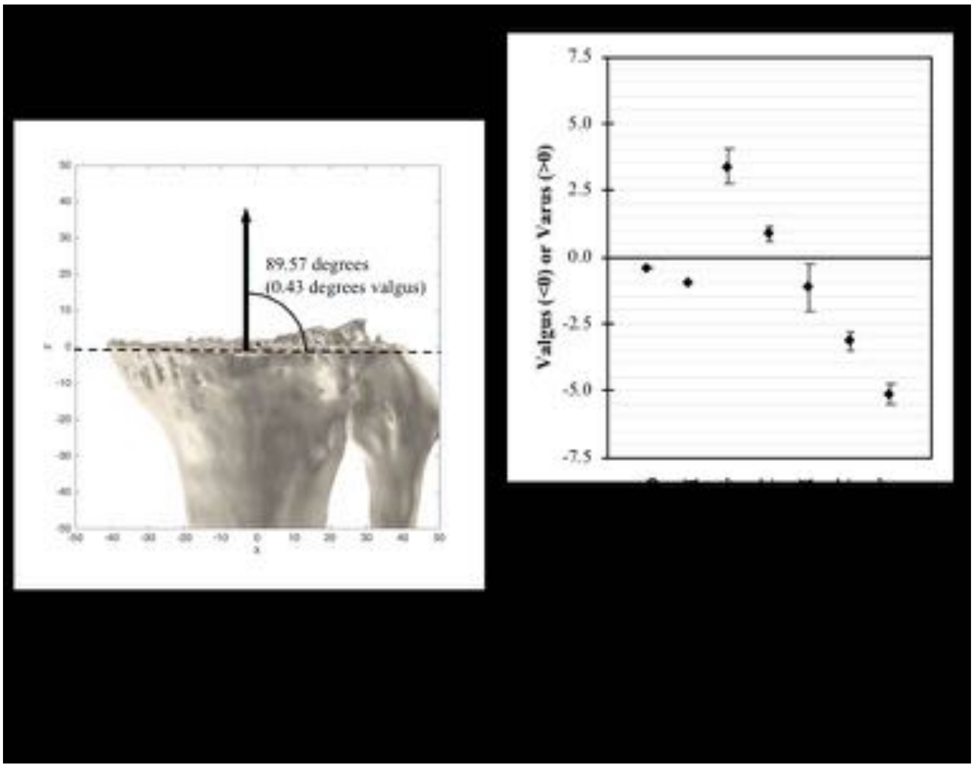
89.57 degrees
(0.43 degrees valgus)
Valgus (<0) or Varus (>0)
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5

Figure 1

#5493

Accuracy of Bone Resection in Total Knee Arthroplasty Using Ct Assisted 3D Printed Patient Specific Cutting Guides in 201 TKAs

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BACKGROUND:

We conducted this study to determine if the pre-surgical patient specific instrumented planning based on Computed tomography scans can accurately predict each of the femoral and tibial resections. The technique helps in optimization of component positioning and hence overall alignment thereby reducing errors. This makes it less invasive, more efficient and cost effective. The surgical plan in combination with the cutting guides determine the resection thickness, component size, femoral rotation and femoral and tibial component alignment. Several clinical studies have shown that PSI is safe, accurate and reproducible in primary TKA. Accurate preparation of the femoral and tibial surfaces will determine alignment and component positioning and this in turn reflects on function and longevity

METHODS:

The study was conducted prospectively between May 2016 and December 2017 in our institution. Patients admitted over a period of these twenty months were included in the study. Patients with primary or secondary osteoarthritis OA and inflammatory arthritis who were suitable to undergo patient-specific TKA were included in the study. Patients with conventional instrumented TKR and those with significant deformities requiring constrain including valgus or varus of greater than 20 degrees with incompetent lateral or medial collateral ligaments were excluded from the study along with revisions of partial knee to TKA using PSI blocks.

Prophecy evolution medial pivot patient specific instrumented knee replacement system were used in all cases. The operating surgeon measured all the resections made (4 femoral and 2 tibial) using vernier calipers intraoperatively. These measurements were then compared with the preoperative CT predicted bone resection surgical planning.

The senior author (IN) also designed markings on the tibial cutting blocks to improve accurate placement on the tibia and further markings on the femoral cutting blocks to ensure accurate positioning and rotational alignment improving accuracy of the cuts and femoral rotation (Fig. 1). Further markings by senior surgeon (IN) on the pre-operative plans included tibial rotational plans in relation to the tibial tubercle (Fig. 2).

RESULTS:

A total of 3618 readings were calculated from 201 knees (105 right and 96 left). There were 112 females and 76 males, and the average age was 67.72 years (44 to 90 years) and average BMI 32.3 (25.1 to 42.3). The surgical time ranged from 46 to 102 minutes with a mean operating time of 62 minutes. All Femoral and Tibial blocks sat accurately on the bony surfaces before being pinned (Figs 3-5). 90% showed resection error ≤1mm (73% had resection error <0.5mm). Mean error of different resections ≤0.60 mm ($P \leq 0.0001$) - Fig 7 and Fig 8.

CONCLUSION:

The 3D printed cutting blocks with slots for jigs accurately predict bone resections in PSI total knee arthroplasty which would directly affect component positioning and hence longevity and function.

Figures

Figure 7: Percentage of Resection Error

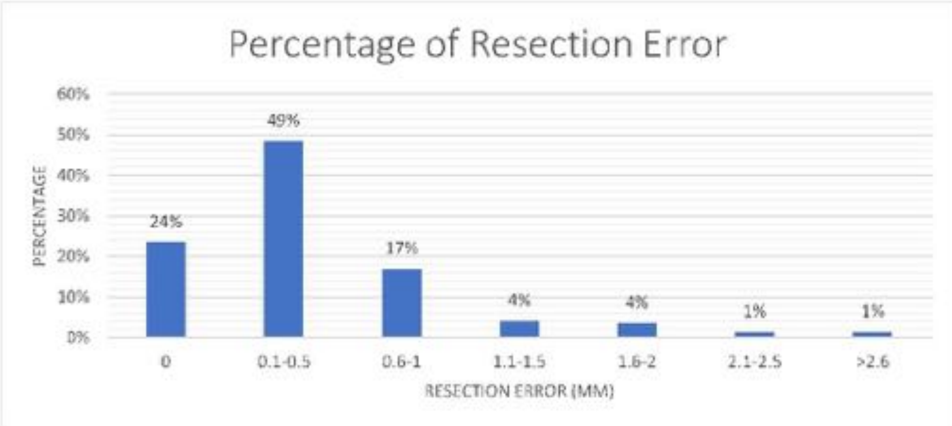

Figure 1

Figure 8: Mean Errors of Different Bone Resections

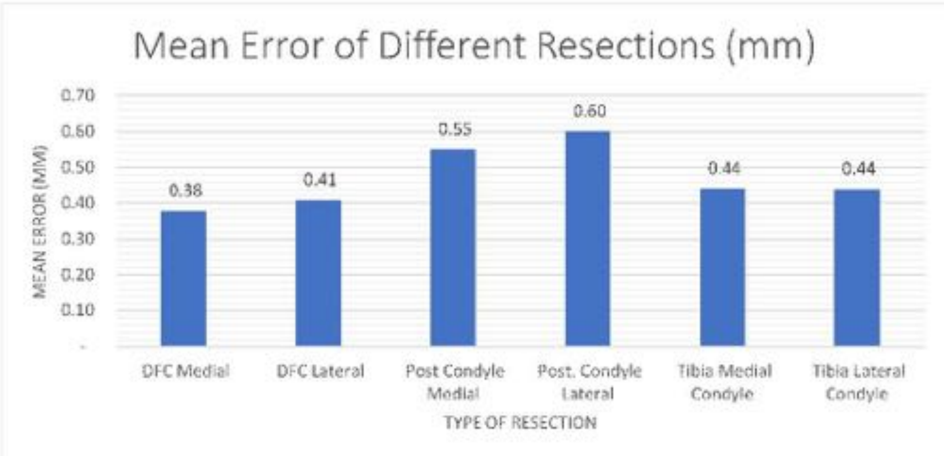

Figure 2

Figure 3: The PSI cutting block placed accurately on the femoral surface and pinned.

Figure 3

Figure 4: Measurement of Medial and Lateral Distal Femoral Condyle and Posterior Condylar cuts

Figure 4

Figure 6: Tibial cut measured from the corresponding points of the plan and recorded for medial and lateral surfaces of tibial plateau.

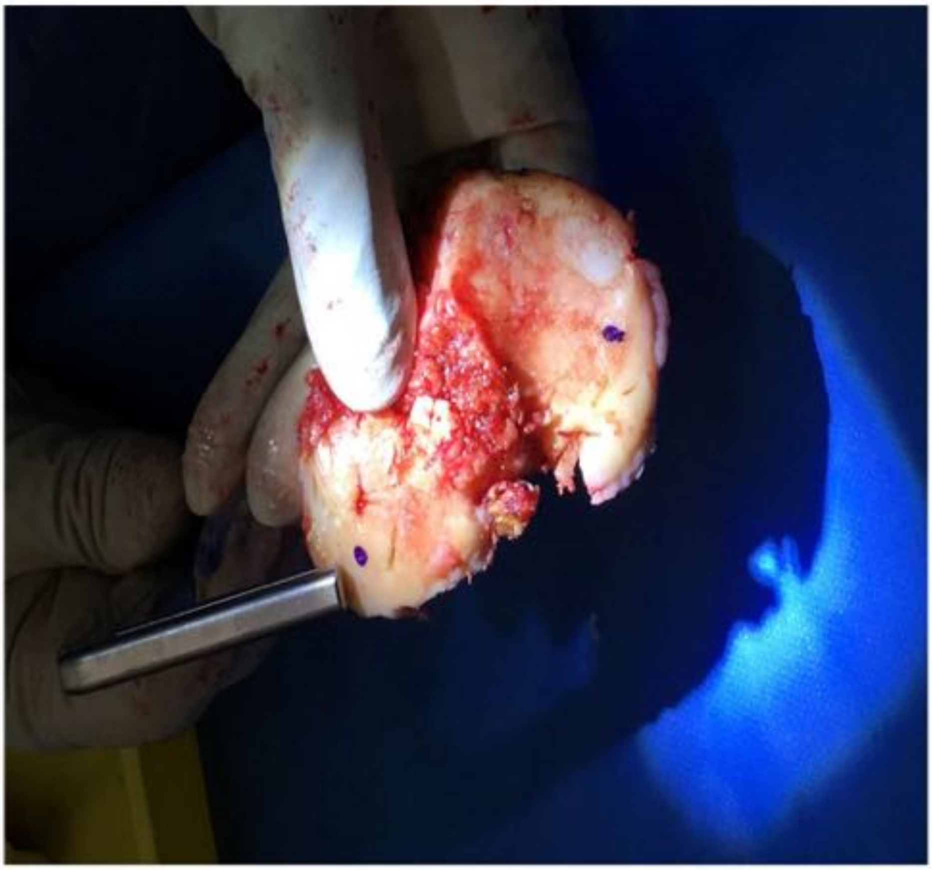

Figure 5

Figure 1: Company manufactured patient specific femur cutting block placed on the respective model on the distal femur.

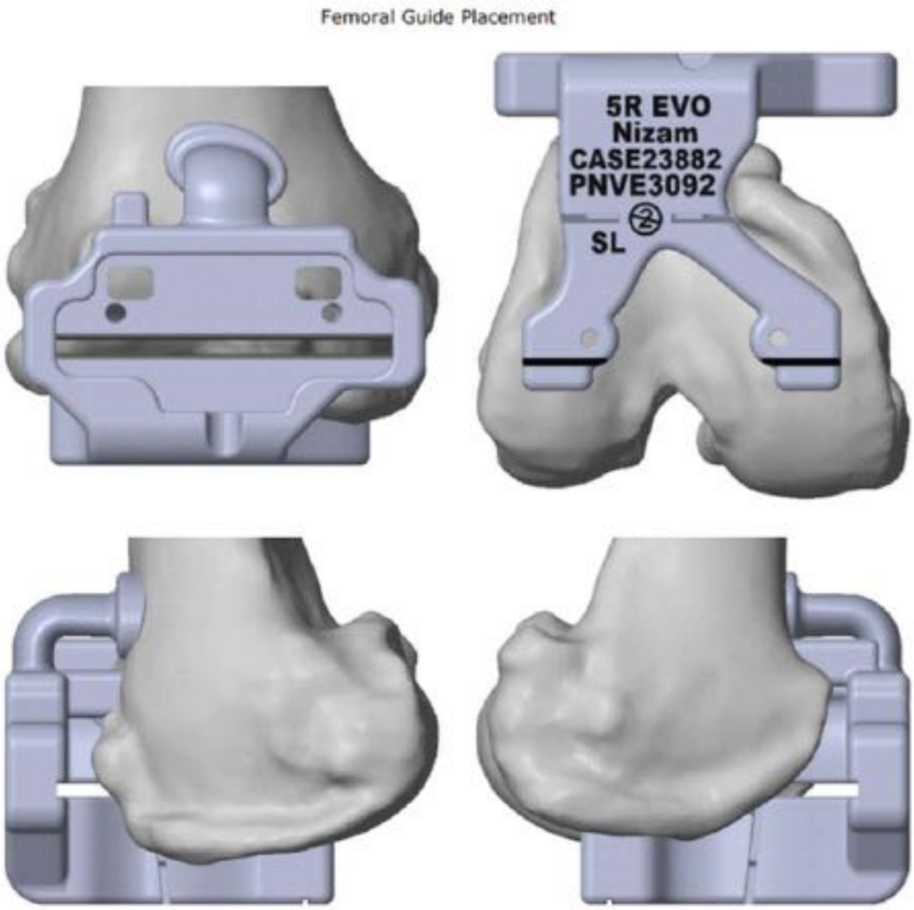

Figure 6

#5884

A Clinical Trial of Next Generation PSI - Robotic Level Accuracy in Less Than Half the Time

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Simon Harris - United Kingdom
Martin Jaere - Imperial College London - London, United Kingdom
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A previous randomised controlled trial (RCT) by our group found that a semi-active robot (Acrobot®) was significantly more accurate than conventional instrumentation in performing unicompartmental knee arthroplasty (UKA)[1]. However, robots are also expensive, and time inefficient. The aim of this clinical study was to determine whether a next generation low-cost PSI design (Embody, London, UK), which uses local and distant bony landmarks, could deliver the same level of accuracy as the robot, whilst also being quicker.

Any patient suitable for a medial UKA was eligible for inclusion. The experimental conditions were identical to the previous RCT: the same validated UKA planning software was used to plan tibial component position using a CT scan derived 3D bone model, Oxford medial UKA prostheses (Zimmer Biomet, Bridgend, UK) were used, and all operations were performed by the same expert surgeon. A day one postoperative CT scan was used in both studies to measure the difference between planned and achieved tibial component position. Operative time was recorded from skin incision to closure. For the PSI group, Oxford knee scores (OKS) and EQ-5D-5L were collected pre-operatively and at 12 months post-operatively.

Thirty patients took part in the study and PSI was used successfully in all cases. The mean absolute difference between planned and achieved tibial implant position was 2º (sd 1) in the coronal plane, 1.8º (sd 1.5) in the sagittal plane, and 4.5º (sd 3.3) in the axial plane. These results were not significantly different to the coronal, sagittal and axial plane accuracy previously observed in thirteen robotic cases (mean difference 0.5º, 0.5º, and 1.7º, p=0.1907, 0.2867 and 0.1049 respectively). Mean operating time (42 min, sd 6) was on average 62 min shorter than the robotic group ($p<0.0001$). There was a significant increase in mean OKS from 28 (range 16-40) pre-operatively to 43 (range 29-48) post-operatively ($p<0.0001$), and in the overall weighted EQ-5D-5L index from 0.5754 (range 0.16-0.77) pre-operatively to 0.8485 (range 0.44-1.00) post-operatively ($p<0.0001$). No complications were reported.

This clinical trial has demonstrated that for tibial component positioning in UKA, a novel design PSI guide in the hands of an expert surgeon, can safely deliver comparable accuracy to a robotic system, whilst being significantly faster and potentially cheaper.

1. Cobb JP *et al*. Hands-on robotic unicompartmental knee replacement:A Prospective,Randomised Controlled Study of the ACROBOT System. *JBoneJtSurgery*.2006;88-B(2):188-197.

#5839

Posterior Condylar Offset Changes and Its Effect on Clinical Outcomes After Posterior-Substituting, Fixed-Bearing Total Knee Arthroplasty: Anterior Versus Posterior Referencing

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Purpose: We sought to determine whether there was a difference in the posterior condylar offset (PCO), posterior condylar offset ratio (PCOR) following total knee arthroplasty (TKA) with anterior referencing (AR) or posterior referencing (PR) systems. We also assessed whether the PCO and PCOR changes, as well as patient factors were related to range of motion (ROM) in each referencing system. In addition, we examined whether the improvements in clinical outcomes differed between the two referencing systems.

Methods: This retrospective study included 130 consecutive patients (184 knees) with osteoarthritis who underwent primary posterior cruciate ligament (PCL)-substituting fixed-bearing TKA. All patients were categorized into the AR or PR group according to the referencing system used. Radiographic parameters, including PCO and PCOR, were measured using true lateral radiographs. The difference between preoperative and postoperative PCO and PCOR values were calculated. Clinical outcomes including ROM and Western Ontario and McMaster University (WOMAC) scores were evaluated preoperatively and at 2 years after TKA. The PCO, PCOR values, and clinical outcomes were compared between the two groups. Furthermore, multiple linear regression analysis was performed to determine the factors related to postoperative ROM in each referencing system.

Results: The postoperative PCO was greater in the AR group (28.4 mm) than in the PR group (27.4 mm), whereas the PCO was more consistently preserved in the PR group. In contrast, there was no difference in the mean postoperative PCOR between the two groups. The mean postoperative ROM after TKA was greater in the AR group (129°) than in the PR group (122°), whereas improvement in WOMAC score did not differ between the two groups. Preoperative ROM was the only factor related to postoperative ROM in both groups.

Conclusions: The postoperative PCO was greater in the AR group, whereas the PCO was more consistently preserved after surgery in the PR group. The postoperative PCO and PCOR changes did not affect the postoperative ROM, regardless of the referencing system used after PCL-substituting fixed-bearing TKA. Furthermore, similar clinical outcomes were achieved in the AR and PR groups.

#6061

Rotation in Total Knee Replacement - Are We Accurate?

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Background

Accurate implant positioning is of supreme importance in total knee replacement (TKR). The rotational profile of the femoral and tibial components can affect outcomes, and the aim is to achieve coronal conformity with parallelism between the medio-lateral axes of the femur and tibia.

Aims

The aim of this study is to determine the accuracy of implant rotation in total knee replacement.

Methods

Intra-operatively, the trans-epicondylar axis of the femur (TEA) and Whiteside's line were used as the reference points, aiming to externally rotate the femoral component by 1 degree. The medial third of the tibial tuberosity was used as the anatomical reference point, aiming to reproduce the rotation of the native tibia.

Pre-and post-operative CT scans were reviewed. The difference in femoral rotation was calculated by determining the femoral posterior condylar axis (PCA) of the native femur pre-operatively and the implant post-operatively. Tibial rotational difference was calculated between the native tibial posterior condylar axis and tibial baseplate.

Results

Pre and post-operative CT scans of 41 knees in 31 patients were analysed. All surgeries were carried out by a single surgeon using the same implant.

The mean difference in rotation of the femur post-operatively was 1.2 degrees external rotation (ER), range -4.7 to 6.9 degrees ER. 83% of femoral components were within 3 degrees of the target rotation.

Mean difference in tibial rotation was -3.8 degrees ER, range -11.1 to 12.4 ER. Only 39% of tibial components were within 3 degrees of the target rotation.

A line perpendicular to the midpoint of the tibial PCA was actually medial to the tibial tubercle in 33 knees, and only corresponded to the medial 1/3 of the tibial tubercle in 8 of 41 knees.

Conclusions

Femoral component rotation is seen to be more accurate than tibial in this group. It may be that the anatomical landmarks used intra-operatively to judge tibial rotation are more difficult to accurately identify. Posterior landmarks are difficult to locate in vivo. This study would suggest that using the anterior anatomical landmark of the medial 1/3 of the tibial tubercle does not allow accurate reproduction of tibial rotation in total knee replacement.

#5912

Accuracy of Intraoperative Robotic-Arm Assisted Total Knee Replacement Alignment With Standing Long Leg Postoperative Alignment

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Purpose: Robotic-arm assistance has recently been introduced into the technique of Total Knee Arthroplasty (TKA). The surgeon can define the alignment of the lower limb while dynamically adjusting implant position and bony cuts. There is a paucity in the current literature concerning the advantages of utilizing robotic assistance over conventional technique. The purpose of this study was to determine intraoperative mechanical alignment accuracy compared with six-week postoperative standing long leg x-rays.

Materials & Methods: A retrospective review of 75 (39 left, 36 right) consecutive robotic assisted TKA procedures performed by a single surgeon was conducted. There were 35 male and 40 female robotic assisted TKAs with a mean age of 69.4 ± 6.1 years. Intraoperative mechanical alignment was determined with automated computed tomography (CT) scan guided infrared navigational software. Postoperative mechanical alignment was determined with standing dual long leg x-rays at the six week follow up interval. Mechanical axis was calculated from these images by drawing a straight line from the center of the femoral head to the intercondylar notch of the distal femur to the center of the ankle. Statistical analysis was primarily descriptive.

Results: Our study found a mean intraoperative mechanical alignment of 1.6Ëš ± 1.2Ëš (left: 1.5Ëš ± 1.2Ëš, right: 1.6 ± 1.3Ëš) and a mean six-week postoperative mechanical alignment of 1.6Ëš ± 1.3Ëš (left: 1.6Ëš ± 1.5Ëš, right: 1.6Ëš ± 1.1Ëš). We found an overall average change in alignment of -0.2Ëš (left: -0.2Ëš, right: -0.3Ëš) when comparing intraoperative alignment to six-week postoperative alignment.

Conclusion: Robotic assisted TKA has a high degree of intraoperative alignment accuracy when compared to postoperative alignment. Knee laterality, pre-operative angular deformity of the index procedure did not affect alignment accuracy. Further studies are necessary to assess the effects of alignment accuracy to postoperative patient reported outcome measures in robotic assisted TKAs.

#5890

Hip Joint Mechanics Before and After Cam Femoroacetabular Impingement

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Introduction

Cam-type femoroacetabular impingement (FAI) is characterized by an enlarged, aspherical femoral head-neck morphology and is associated with early hip joint degeneration, limited joint mobility, and adverse loading. While surgical management of cam FAI aims to preserve the native hip and restore joint function, it is unclear how the capsulotomy, cam deformity, and capsular repair influence functional mobility. The purpose was to examine the contributions of the capsule and cam deformity to FAI. Using in vitro, cadaveric methods, we examined the individual effects of the surgical capsulotomy, cam resection, and capsular repair towards functional range of motion and torque resistance.

Methods

Twelve fresh, frozen cadaveric hips (n = 12 males, age = 45 ± 9 years, BMI = 24 ± 3 kg/m^2) were included in this study. Each hip was CT imaged to confirm cam morphologies (as indicated by elevated alpha angles) and was then skeletonized to the capsule and mounted onto a robotic testing platform. The robot positioned each hip in multiple positions: 1) Extension, 2) Neutral 0°, 3) Flexion 30°, 4) Flexion 90°, 5) flexion-adduction and internal rotation (FADIR), 6) flexion-abduction and external rotation (FABER); and performed internal and external rotations, recording the neutral path of motion until a 5-Nm torque was reached in each direction. Each hip then underwent a series of surgical stages (Figure 1; T-capsulotomy, cam resection, capsular repair) and was retested to reach 5 Nm torque after each stage. In addition, during the capsulotomy and cam resection stages, the initial intact hip's recorded path of motion was replayed to measure changes in resisted torque.

Results

Examining changes in motion, external rotation increased substantially after capsulotomies (Figure 2), but internal rotation only increased at Flexion 90° (change = +32%, p = 0.001, d = 0.58) and FADIR (change = +33%, p < 0.001, d = 0.51) after cam resections. Capsular repair provided marginal internal rotation restraint, but restrained the external rotation compared to the capsulotomy stage. Examining changes in torque, both internal and external torques decreased after capsulotomy (Figure 3). Cam resection further reduced internal torques during Flexion 90° (change = –45%, p < 0.001, d = 0.98) and FADIR (change = –37%, p = 0.003, d = 1.0), where the cam deformity accounted for 21% in Flexion 90° and 27% in FADIR of the intact hip's torsional resistance.

Discussion

Although the capsule played a predominant role in joint constraint, the cam deformity provided 25% of the intact hip's resistance to torsional load in flexion and internal rotation. This further contributes to the understanding of the cam morphology and the role of surgical management in joint preservation strategies. Interestingly, the FABER test may be more practical during clinical examinations to indicate capsule tightness or soft tissue impingement, whereas FADIR can indicate bone-on-bone cam impingement. These findings are the first to quantify the contribution of the cam deformity to resisting hip joint torsional loads and thus quantify the reduced loading on the chondrolabral complex that can be achieved after cam resection.

Figures

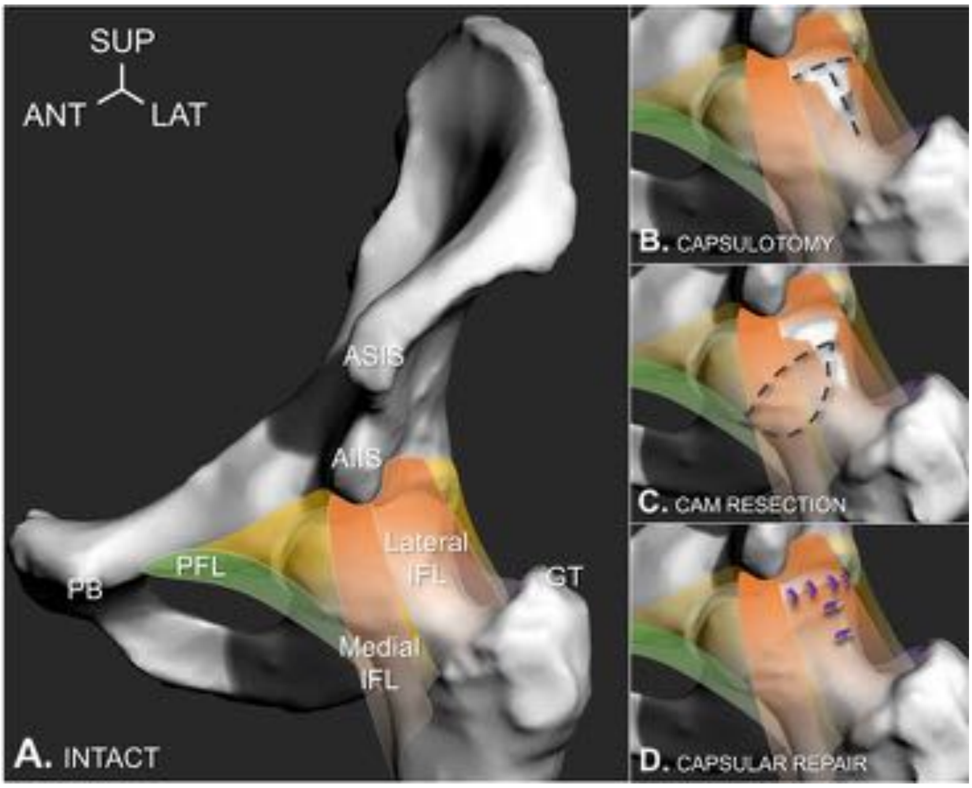

Figure 1

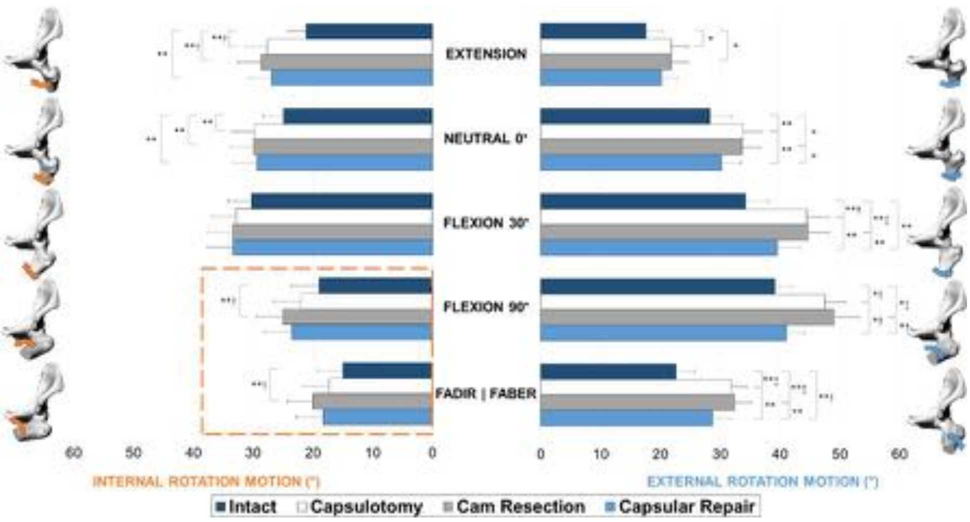

Figure 2

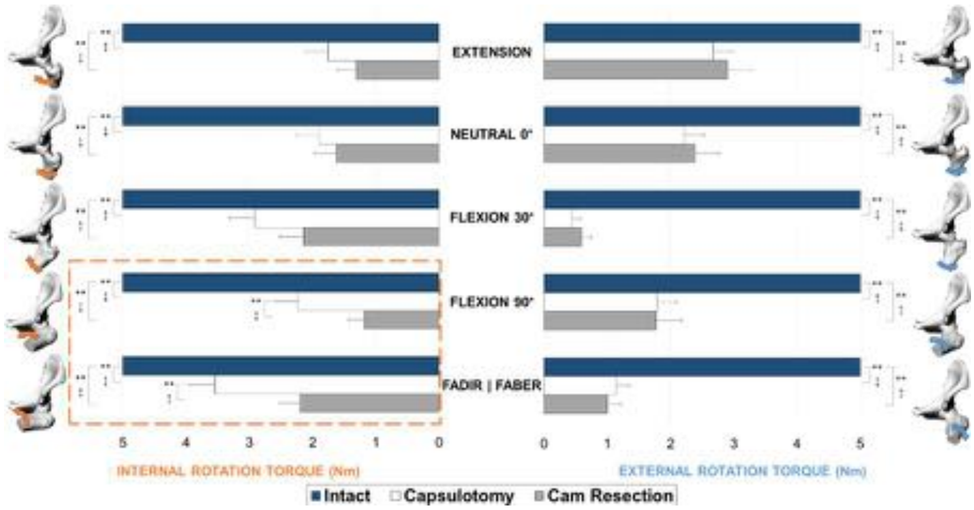
EXTENSION
NEUTRAL 0°
FLEXION 30°
FLEXION 90°
FADIR | FABER
INTERNAL ROTATION TORQUE (Nm)
EXTERNAL ROTATION TORQUE (Nm)
Intact
Capsulotomy
Cam Resection

Figure 3

#5577

Joint Distraction for Knee Osteoarthritis: A Systematic Review and Quantitative Analysis

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Introduction: Knee osteoarthritis is the most common form of osteoarthritis and a major cause of pain and disability. However, there remains a lack of treatments available that have demonstrated effectiveness in stopping or reversing the degenerative process. Joint distraction has emerged as a viable alternative in the treatment of knee osteoarthritis to delay the need for knee arthroplasty. This systematic review aims to assess the short- and long-term clinical and structural outcomes following knee joint distraction (KJD).

Methods: MEDLINE and EMBASE databases were searched from the date of inception to 24th January 2017. Clinical studies investigating joint distraction for knee osteoarthritis, which reported outcomes such as âˆ†WOMAC index, âˆ†VAS pain score and âˆ†joint space width were included. Quality assessment was performed using the Modified Coleman Methodology Score (MCMS). The risk of bias was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies and Cochrane Collaboration tool for randomised controlled trials (RCTs).

Results: Six studies comprising a total of 367 patients were included. Three open prospective cohort studies evaluated the effects of KJD at 1-, 2- and 5-years, respectively. One open prospective cohort study compared the outcomes following six- versus eight-weeks of KJD at 1 year. There were two RCTs involving KJD with a follow-up of 1 year; one which compared KJD with high tibial osteotomy (HTO) and another with total knee arthroplasty (TKA). Overall, there were significant improvements in WOMAC index, VAS pain score and joint space width following KJD, which persisted up till five years. KJD also demonstrated comparable clinical outcomes with HTO and TKA. The mean MCMS score was 84.2 out of 100, with all studies scoring at least 80. Three studies scored 8/9 on the NOS while one study scored 9/9. Both RCTs were found to be at high risk of performance and detector bias.

Conclusion: There is moderate quality evidence supporting the beneficial outcomes of joint distraction for knee osteoarthritis. Larger RCTs with longer follow-up (>1 year) are necessary to establish the true effect size of this procedure.

Bisphosphonate Prematurely Ages Bone Matrix Mechanics

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Introduction: Osteoporosis is a metabolic bone disorder characterized by the loss of bone mass and consequently, increased risk of fracture. This condition affects 200 million individuals worldwide, with a high prevalence in the elderly. Bisphosphonates are potent anti-resorptive agents used as the first-line treatment of this condtion. The present study aims to investigate and compare the mechanical behaviour of the collagen-mineral matrix under tensile loading between bisphosphonate-treated, osteoporotic and healthy bone, using synchrotron small angle X-ray scattering (SAXS) and wide angle X-ray diffraction (WAXD) techniques.

Method: Trabecular bone samples were obtained from the femoral heads of bisphosphonate-treated, osteoporotic (fracture control group) and healthy ageing (non-fracture control group) individuals. Samples underwent tensile testing, during which SAXS and WAXD spectra were obtained. Tensile testing was displacement-controlled, with a strain rate of 0.001 s^{-1}, with an average time of 2 minutes per sample. Samples were scanned (X-ray exposure time of 0.5 s) in real-time during testing at 2.5 second intervals. All tests were conducted at room temperature and the specimens were kept hydrated throughout testing.

Results: The bisphosphonate therapy group exhibited the lowest yield stress point across all groups, followed by the fracture control and non-fracture control groups. The differences observed across the three groups were statistically significant. Correspondingly, the bisphosphonate therapy group demonstrated the lowest fibril and mineral strain, followed by the fracture and non-fracture control groups (Figure 1). Similarly, a statistically significant difference was noted across all groups.

Discussion: In the present study, bisphosphonate-treated and osteoporotic bone exhibited reduced elasticity and deformability in the collagen-mineral matrix. These differences observed can be attributed to variability in the properties of collagen in bisphosphonate-treated and osteoporotic bone compared to healthy bone, including cracking of bone mineral crystallites, de-bonding at the mineral organic interface or shear between and within collagen fibrils, all of which increase fracture risk.

Conclusion: The nanostructural changes occurring in bisphosphonate-treated and osteoporotic bone are likely to play an important role in the pathophysiology of fractures in these patients. Hence, the present findings will set the foundations for future work investigating how alterations in collagen cross-links and mineralization occur within the nanostructure, which will be essential in furthering our current understanding of fractures.

Figures

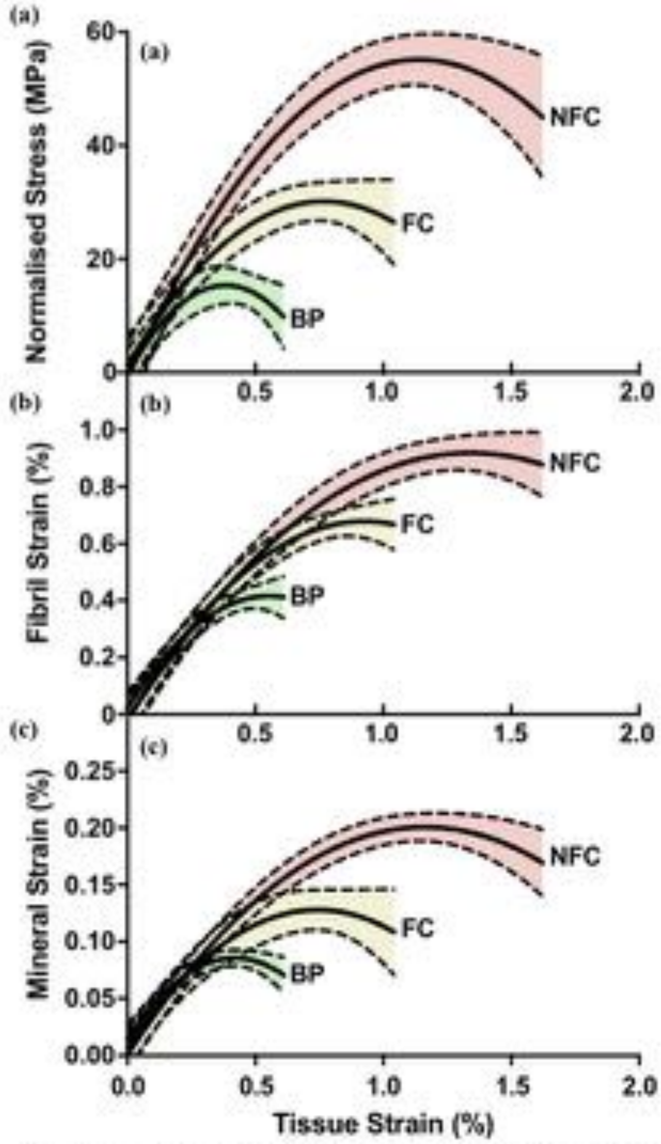

Figure 1. Overall mechanical characteristics. (a) Overall normalised stress-strain curves are shown for the non-fracture control (NFC), fracture control (FC) and bisphosphonate therapy (BP) groups. (b) Overall fibril-tissue strain curves are shown for the NFC, FC and BP groups. (c) Overall mineral-tissue strain curves are shown for the NFC, FC and BP groups. The shaded area represents the 95% confidence intervals for each group.

Figure 1

#6060

Hip Capsule Function in the Natural and Implanted Hip

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Introduction: Management of the hip capsule is a critical component of successful total hip arthroplasty (THA). The hip capsule is comprised of the iliofemoral, ischiofemoral, and pubofemoral ligaments, which form a continuous structure encapsulating the joint, stabilizing the hip, and preventing dislocation. During THA, the capsule is sectioned along either the anterior or posterior aspect, depending on the surgical approach. Capsule repair after THA is both difficult and controversial. Many surgeons forgo repair of the capsule and rely on scar tissue formation and muscle tension to stabilize the hip after surgery. The hypothesis of this study was that disruption of the hip capsule during THA increases hip laxity.

Methods: Capsular function was assessed in six intact cadaveric hips and six hips implanted with THA through a posterior incision (Pinnacle™ cup and Summit™ stem, DepuySynthes, Inc). After surgery, each specimen was dissected to expose the hip capsule, sectioned above and below the joint, and cemented into custom fixtures. The hip was mounted in an AMTI VIVO joint simulator such that the femoral head center was aligned with the three rotational axes of the loading rig (Fig. 1). Rotational laxity assessments were performed in 15° flexion increments from full extension to 90° flexion. At each flexion angle, adduction-abduction (Ad-Ab) hip torque-rotation curves were assessed at three internal-external (I-E) hip positions (neutral, internal, and external limits). Likewise, I-E torque-rotation curves were assessed at three Ad-Ab hip positions (neutral, adduction, and abduction limits, Fig. 1). Hip rotations were extracted at ±3N-m of I-E and Ad-Ab torques through the flexion range and averaged across natural and implanted cohorts. The hip capsule in select specimens were stained with Methyl Blue and misted with white paint to create a high-contrast stochastic pattern. A digital image correlation (DIC) system (Aramis, GOM) was used to quantify strain patterns in the iliofemoral ligament during the laxity assessments.

Results: THA reduced femoral adduction rotation through the flexion range and external rotations in mid-flexion. Conversely, THA and incision of the posterior hip capsule dramatically reduced resistance to internal femoral rotation. Natural hip adduction in deeper flexion and THA hip internal rotations exceeded the limits of the loading rig or impinged prior to reaching the target torques making statistical comparisons difficult. Hip Ad-Ab and I-E rotations at neutral alignment through the flexion range for the natural and THA cohorts are show in Fig. 2. Exemplary strain patterns in the iliofemoral ligament during hip adduction are shown in Fig. 3.

Discussion: Reductions in femoral adduction and external rotations after THA likely indicate that lateralization of the cup or increased femoral offset tensioned the anterior and superior aspects of the capsule. Incision of the posterior hip capsule markedly reduced resistance to internal hip rotation but did not increase laxity in the other degrees of freedom. Ongoing work is focused on development of finite element representations of the capsule to accurately predict coupled I-E and Ad-Ab hip laxity through the flexion range, with model verification provided by these experimentally measured hip capsule laxities and strain patterns.

Figures

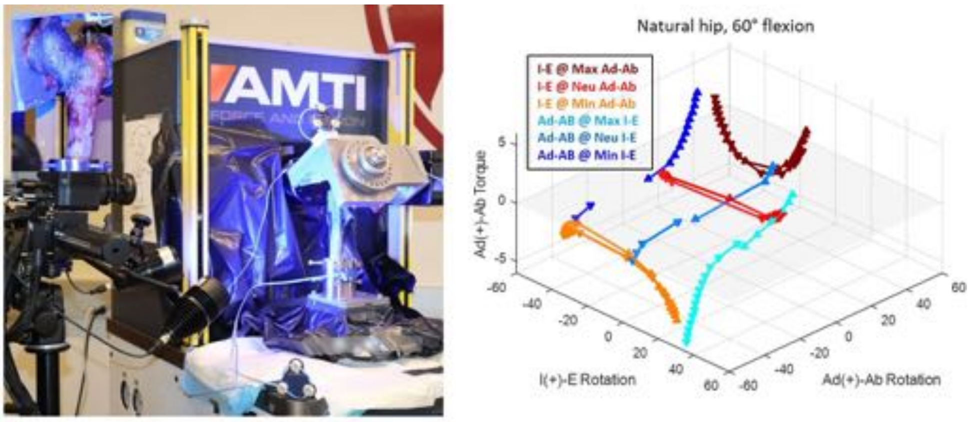

Fig. 1: Experimental setup of an AMTI VIVO joint simulator with custom fixtures to test cadaveric hips and DIC system measuring strain in the iliofemoral ligament (left). Example Ad-Ab torque response of the hip capsule to combined Ad-Ab and I-E femoral rotations.

Figure 1

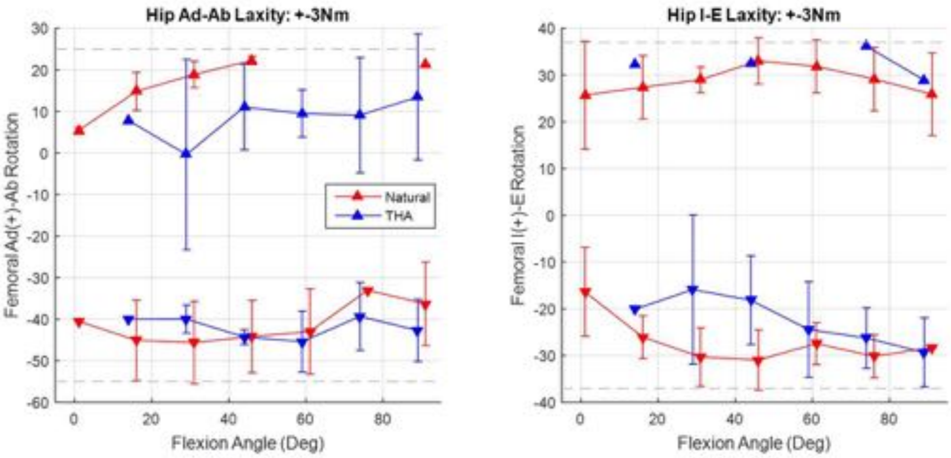

Fig. 2: Hip Ad-Ab (left) and I-E (right) rotations under ± 3 Nm of Ad-Ab and I-E torque, respectively, through the flexion range for natural (red) and implanted (blue) hips. Gray dashed lines represent the physical rotational limits of the mechanical rig used to conduct the testing.

Figure 2

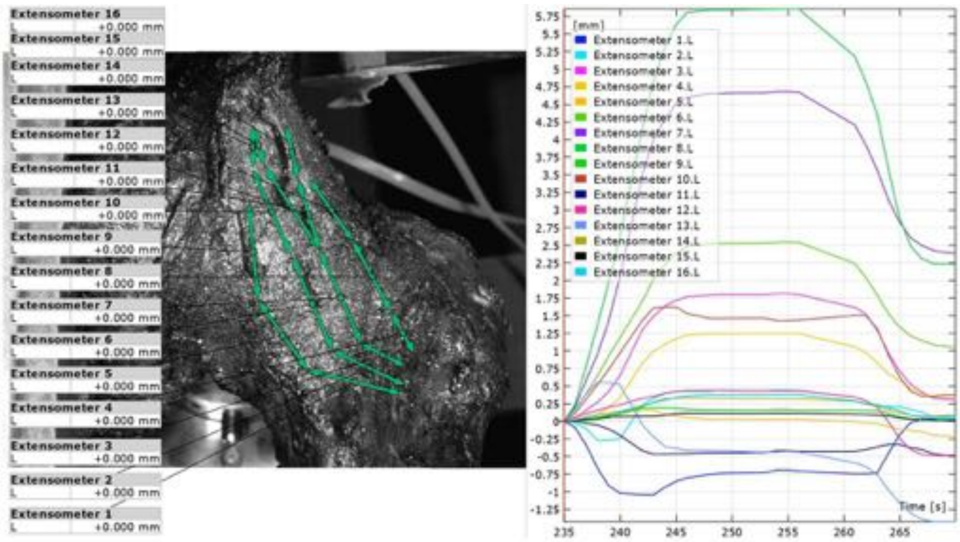

Fig. 3: Displacements of multiple virtual extensometers on the surface of the iliofemoral ligament during hip adduction.

Figure 3

Spinopelvic Compensatory Mechanisms for Reduced Hip Motion in the Setting of Hip Osteoarthritis

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Introduction: Hip osteoarthritis (OA) results in reduced hip range of motion and contracture, affecting sitting and standing posture. Spinal pathology such as fusion or deformity may alter the ability to compensate for reduced joint mobility in sitting and standing postures. The effects of postural spinal alignment change between sitting and standing is not well understood.

Methods: A retrospective radiographic review was performed at a single academic institution of patients with sitting and standing full-body radiographs between 2012 and 2017. Patients were excluded if they had transitional lumbosacral anatomy, prior spinal fusion or hip prosthesis. Hip OA severity was graded by the Kellgren-Lawrence grades and divided into two groups: low-grade OA (LOA; grade 0-2) and severe OA (SOA; grade 3-4). Spinopelvic parameters (Pelvic Incidence (PI), Pelvic Tilt (PT), Lumbar Lordosis (LL), and PI-LL), Thoracic Kyphosis (TK; T4-T12), Global spinal alignment (SVA and T1-Pelvic Angle; TPA; T10-L2) as well as proximal femoral shaft angle (PFSA: as measured from the vertical), and hip flexion (difference between change in PT and change in PFSA) were also measured. Changes in sit-stand radiographic parameters were compared between the LOA and SOA groups with unpaired t-test.

Results: 548 patients were identified with sit-stand radiographs, of which there were 311 patients with LOA & 237 with SOA. After propensity score matching for Age, BMI, and PI, 183 LOA & 183 SOA patients were analyzed.

Standing alignment analysis demonstrated that SOA patients had greater SVA (31.1 ± 36.68 vs 21.7 ± 38.83, p=0.02), and lower TK (-36.21 ± 11.98 vs -41.09 ± 11.47, p<0.001). SOA patients had lower PT, greater PI-LL, lower LL, lower T10-L2, and lower TPA (p>0.05). PFSA (9.09 5.19 vs 7.41 4.48, p<0.001) was significantly different compared to LOA while SOA KA was not significantly different compared to LOA.

Sitting alignment analysis demonstrated that SOA patients had higher PT (29.69 ± 15.65 vs 23.32 ± 12.12, p<0.001), higher PI-LL (21.64 ±17.86 vs 12.44 ±14.84 p<0.001), lower LL (31.67 ± 16.40 vs 41.58 ± 14.73, p<0.001), lower TK (-33.22 ± 15.76 vs -38.57 ± 13.01, p=0.01), greater TPA (27.91 ± 14.7 vs 22.55 ± 11.38 p=0.01). TK, SVA, and PFSA were not significantly different compared to LOA

SOA and LOA groups demonstrated differences in standing and sitting spinopelvic alignment for all global and regional parameters except PI. When examining the postural changes from standing to sitting, there was less hip ROM in SOA than LOA (71.45 ±

18.55 vs 81.64 ± 12.57, p<0.001). As a result, SOA patients had more change in PT (15.24 ± 16.32 vs 7.28 ± 10.19, p<0.001), PI-LL (20.62 ± 17.25 vs 13.74 ± 11.16, p<0.001), LL (-21.37 ± 15.55 vs -13.09 ± 12.34, p<0.001), and T10-L2 (-4.94 ± 7.45 vs -1.08 ± 5.19, p<0.001) to compensate. SOA had a greater improvement in TPA (15.06 vs 9.59, p<0.001), and less change in PFSA (86.65 vs 88.81, p<0.001) compared to LOA

Conclusions: Spinopelvic compensatory mechanisms are adapted for reduced joint mobility associated with hip OA in standing and sitting.

#6120

Hip Arthroscopy Improves Patient Satisfaction in All Patients Regardless of Age

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Introduction:

Hip arthroscopy is an increasingly popular procedure to treat various hip pathologies with favorable outcomes. Several studies have stated that as patients age, the likelihood of failure after hip arthroscopy increases, defined as subsequent total hip arthroplasty THA. The aim of this study is to investigate the relationship between patient reported outcome measures after hip arthroscopy and patient age.

Methods:

After IRB approval, all patients undergoing hip arthroscopy from 2008–2016 were reviewed. To be included patients must have had a minimum of 1-year follow-up. Prospectively collected data included patient age at surgery, body mass index (BMI), ethnicity, and outcome measures. The outcome measures investigated included the Harris Hip Score (HHS), and both the physical (PSF) and mental (MSF) components of the Short-Form-12 score. Data were collected preoperatively and at post-operative intervals of 6-weeks, 3-months, 6-months, 1-year, 2-years, and 3-years. Patients were stratified into cohorts based on age at time of surgery: ≤15, 16-25, 26-35, 36-45, 46-55, and >55 years old (yo).

Results:

A total of 484 patients were included in this study. Overall there was improvement in HHS, PSF, and MSF ($p<0.0001$, $p<0.0001$, and $p=0.0425$, respectively). At 1-year, those ≤15yo had the greatest increase in HHS (increase of 25.64), however this decreased by 3-years (increase of 19.92 from pre-operative), where those ages 46-55 continued to improve through 3-years (increase of 30.59). Those ages 46-55 saw the greatest increase in PSF scores at 1-year (15.77) and at 3-years (18.33). MSF scores increased for all age groups, though this increase was small it was significant.

Conclusion:

All patients, regardless of age, have improvement in outcome measures after hip arthroscopy. This includes older patients, where this procedure may offer symptomatic relief and delay the need for other procedures, including THA.

#5895

Altered Walking and Muscle Patterns Reduce Hip Contact Forces in Individuals With Symptomatic Cam FAI

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Introduction

Cam-type femoroacetabular impingement (FAI) is a causative factor for hip pain and early hip osteoarthritis. Although cam FAI can alter hip joint biomechanics, it is unclear what role muscle forces play and how they affect the hip joint loading. Moreover, bone-on-bone impingement is less likely to occur during level walking, given that the task involves a less demanding range of motion. This suggests that there may be other parameters, in addition to the bony deformity, that could alter walking biomechanics of FAI participants. The purpose was to examine the muscle contributions and hip contact forces in individuals with symptomatic cam FAI during level walking.

Methods

Eighteen patients with symptomatic cam FAI (n_{FAI} = 18) were age- and BMI-matched with eighteen control participants (n_{CON} = 18). At the motion capture laboratory (Figure 1), each participant's walking kinematics and kinetics were recorded throughout a gait cycle (ipsilateral foot-strike to ipsilateral foot-off), using a ten-camera motion capture system (Vicon MX-13) and two fixed force plates (Bertec Corporation FP4060-08). Hip muscle and joint contact forces were subsequently computed using a musculoskeletal modelling program (OpenSim 3.1), by scaling the computational model and static optimization, and were normalized by bodyweight. Hip contact forces were calculated as three-dimensional vectors acting on the acetabulum and expressed in the pelvic coordinate system.

Results

The FAI group walked slower and with shorter steps, demonstrating reduced joint motions and moments during contralateral foot-strike, compared to the CON group. The FAI group also showed reduced psoas major (median = 1.1, interquartile range (IQR) = 1.0–1.5 Newton/bodyweight (N/BW)) and iliacus forces (median = 1.2, IQR = 1.0–1.6 N/BW), during contralateral foot-strike, compared to the CON group (median = 1.6, IQR = 1.3–1.6 N/BW, $p = 0.004$; and median = 1.5, IQR = 1.3–1.6 N/BW, $p = 0.03$, respectively; Figure 2). This resulted in lower hip contact forces for the FAI group, in the anterior ($p = 0.026$), superior ($p = 0.02$), and medial directions ($p = 0.038$). The three vectors produced a resultant peak force at the anterosuperior aspect of the acetabulum for both groups; with the FAI group demonstrating a substantially lower magnitude (Figure 3).

Discussion

FAI participants altered their walking kinematics and kinetics, especially during contralateral foot-strike, which can be interpreted as a protective mechanism and resulted in reduced psoas major and iliacus muscle force and anterosuperior hip contact force estimations. These findings can provide guidance in optimizing non-surgical management as well as postoperative protocols for the treatment of symptomatic FAI. Limited hip mobility is not only attributed to bone-on-bone impingement, caused by the cam morphology, but could be attributed to musculature as well. Not only would the psoas major and iliacus be able to protect the hip joint during flexion-extension, athletic conditioning could further strengthen core muscles for improved hip mobility and pelvic balance.

Figures

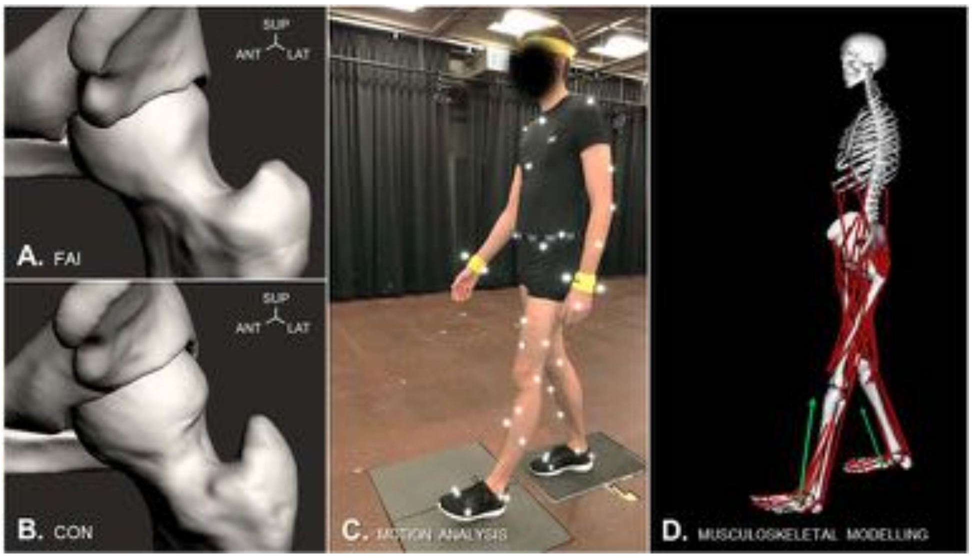


Figure 1

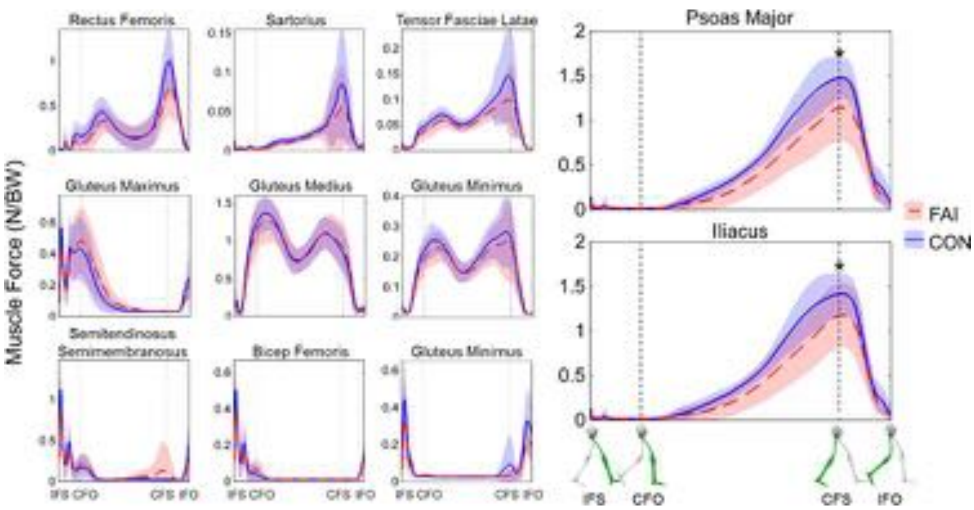
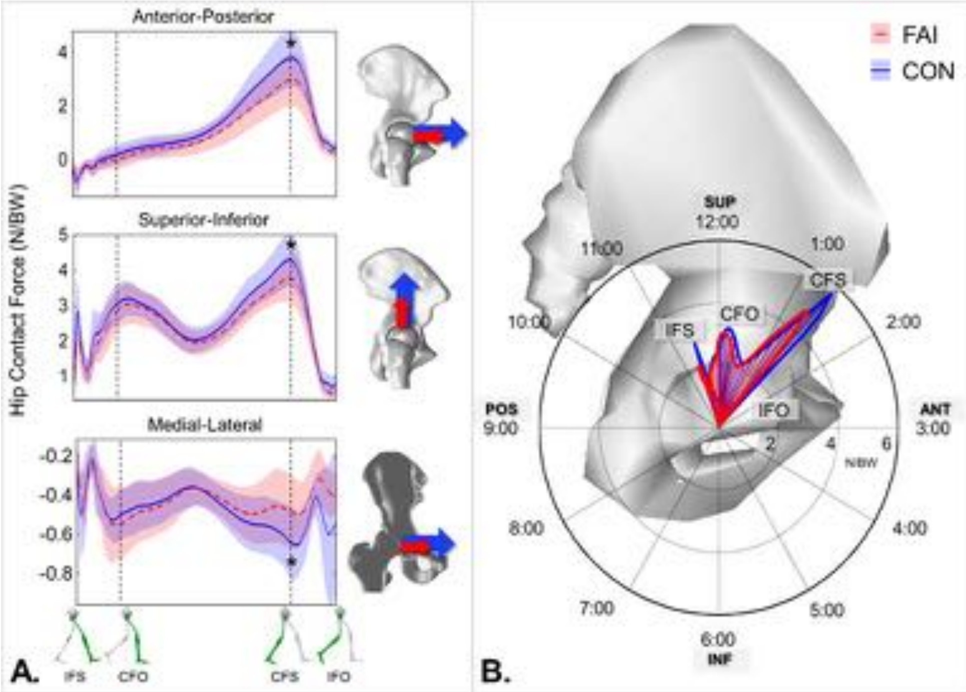


Figure 2



Anterior-Posterior
Superior-Inferior
Medial-Lateral
Hip Contact Force (N/BW)
IFS
CFO
CFS
IFO
A.
B.
FAI
CON
SUP
12:00
1:00
2:00
ANT
3:00
4:00
5:00
6:00
INF
7:00
8:00
POS
9:00
10:00
11:00
N/BW

[Figure 3](#)

#6085

Sitting-Standing Spinopelvic Mechanisms Predict Risk of Dislocation After Total Hip Arthroplasty

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INTRODUCTION: Osteoarthritis (OA) of the hip can affect range of motion. In patients with total hip arthroplasty (THA), the angles of the acetabular component change with postural changes, affecting the stability and wear of the implants. Previous studies have suggested that pelvic spatial position during postural change predisposes these patients to risk of dislocation. The purpose of our study was to analyze segmental spinal alignment between sitting and standing, and the effects of stiff and hypermobile pelvises to determine the lumbopelvic mechanics affecting risk of dislocation.

METHODS: Segmental spinal alignment and lumbopelvic alignment (pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), PI-LL, sacral slope) were analyzed. Patients were classified based on spine and pelvis stiffness (change in PT from standing to sitting) into three categories: STIFF (<20°), NORMAL (20°-35°), and hypermobile (HYPER; >35°). Exclusion criteria included lumbar fusion/ankylosis, hip arthroplasty, lumbar flatback deformity, and transitional lumbosacral anatomy. Independent samples t-tests analyzed lumbopelvic and segmental alignment between sitting and standing within groups. ANOVA assessed these differences between spine pathology groups.

RESULTS: There were 86 NORMAL, 297 STIFF and 16 HYPER patients with significant differences BMI and hip OA grades. Significant differences were noted between groups with regard to changes from standing to sitting alignment with regard to STIFF vs NORMAL vs HYPER groups in PT (5.8° vs 25.7° vs 44.6°; p<0.001), LL (-14.2° vs -33.8° vs -39.8°; p<0.001), PI-LL (13.1° vs 35.2° vs 46.3°; p<0.001),

STIFF patients had overall less mobility in the lumbar spine from standing to sitting compared to NORMAL and HYPER patients, respectively, with regards to changes in L1-L2 (-0.7° vs -2.0° and -2.7°, p<0.001), L2-L3 (-1.0° vs -3.7° vs -3.8°, p<0.001), L3-L4 (-1.9° vs -5.7° vs -7.7°, p<0.001), L4-L5 (-4.0° vs -7.6° vs -7.7°, p<0.001) and L5-S1 (-3.7° vs -5.2° vs -5.8°, p<0.039).

CONCLUSION: In patients with severe hip OA, changes in hip range of motion from standing to sitting do not occur at the hip, but rather the spine. We believe that severe OA and limited preoperative hip range of motion are the main determinants controlling postoperative risk of dislocation. As such, arthroplasty surgeons cannot assume that joint range of motion will be the same after surgery and must avoid overcorrecting for pelvic tilt to mitigate the risk of postoperative dislocation.

#5738

Standing to Sitting Is Not Only Pelvic Rotation: Description and Quantification of the Combined Pelvic Translation. EOS Evaluation Comparing Pre and Post Op Data in THA Patients.

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Introduction:

Literature describes pelvic rotation on lateral X rays from standing to sitting position. EOS full body lateral images provide additional information about the global posture. The projection of the vertical line from C7 (C7 VL) is used to evaluate the spine balance. C7 VL can also measure pelvic sagittal translation (PST) by its horizontal distance to the hip center (HC). This study evaluates the impact of a THA implantation on pelvic rotation and sagittal translation.

Material and Method:

Lumbo-pelvic parameters of 120 patients have been retrospectively assessed pre and post-operatively on both standing and sitting acquisitions (primary unilateral THA without complication). PST is zero when C7VL goes through the center of the femoral heads and positive when C7VL is posterior to the hips' center (negative if anterior). Three subgroups were defined according to pelvic incidence (PI): low PI <45°, 45°<normal PI<65° or high PI>65°.

Results:

Pre-operatively PST standing was -0.9 cm (SD 4.5; [-15.1 to 7.2]) and PST sitting was 1.3cm (SD 3.3; [-7.7 to 11.8]). The overall mean change from standing to sitting was 2.2 cm ([-7.2 to 17.4]) (p<0.05).

Post-operatively PST standing was 0.2 cm (SD 4.7; [-17 to 8.1]) and PST sitting was 1.4cm (SD 3.5; [-7.3 to 10.4]).The overall mean change from standing to sitting was 1.2 cm ([-14.2 to 22.4]) (p<0.05).

In low PI group pre and post-operatively, PST increased significantly from standing to sitting (p<0.05; with HC going anterior to C7VL). When comparing pre and post operative changes, standing PST significantly increased (p=0.001).Pre to postoperative PST variation (sitting-standing) decreased significantly (p=0,01).

In normal PI group pre-operatively, PST increased from standing to sitting (p=0.004). When comparing pre and postoperative changes, PST increased (p=0.006). Pre to postoperative PST variation (sitting-standing) decreased significantly (p=0,04).

In high PI group pre and post operatively, PST increased from standing to sitting (p=0.034) while there are no significant changes from pre to post-operative status in standing and in sitting.

Discussion:

Anteroposterior pelvic tilt is not the only adaptation strategy for postural changes from standing to sitting positions. Anteroposterior pelvic translation (quantified by PST) is an important adaptation mechanism for postural changes. Comparison of pre and post-operative values of PST points out the importance of pelvic translation for low and standard PI patients after THA (fig 1,2).

The anteroposterior translation appears to change significantly in different functional positions pre and post operatively. This is an important variable to consider when assessing the patients' posture change or investigating the causes of the hip dislocation after total hip arthroplasty or spinal fusion.

Conclusion:

Pelvic translation must be considered as a significant mechanism of adaptation after THA. Further studies are needed to study the impact on subluxation or dislocation.

<u>Figures</u>

Figure 1

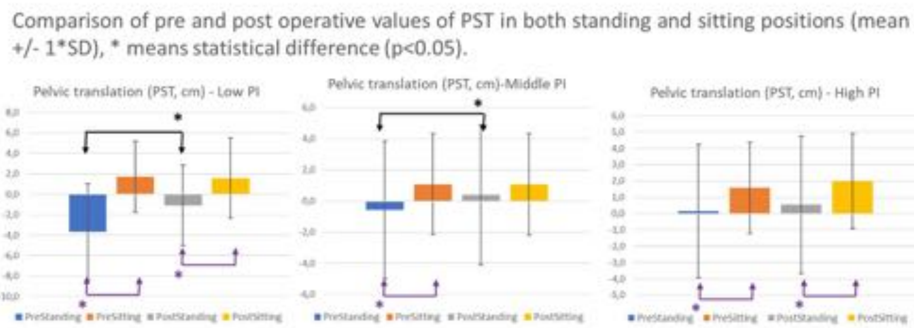

Figure 1

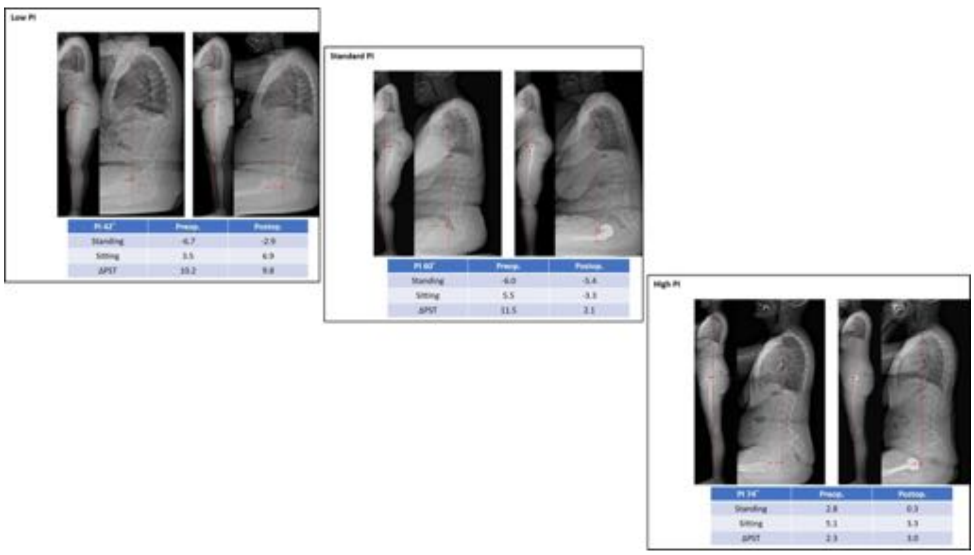

Figure 2

#5742

Quantitative Analysis of the Stand to Sit Pelvis Kinematics Using 3D Reconstructions From Bi-Planar X-Rays

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Introduction

Stand to sit pelvis kinematics (SSPK) is commonly considered as a rotation around the femoral head. However, abnormal kinematics could occur for patients with musculoskeletal disorders. Using 3D reconstruction from bi-planar x-rays, the aim of this study is to perform a quantitative analysis of the SSPK.

Material and Methods

26 patients were considered, 11 asymptomatic (43±11y, 5males) and 15 pathological subjects (36.9±10.2y, 4males), with spine (9 subjects) and /or hip (7 subjects) disorders.

Acquisition was performed using low dose bi-planar x-ray in controlled standing and sitting position. 3D reconstruction was performed in each configuration and then translated such as the middle of the line joining the two pelvic acetabulums (Lc) corresponds to the origin. From these two positions, rigid registration allows to quantify the finite helical axis (FHA) parameters (α represents the absolute angle around this FHA, β is the absolute 3D angle between the FHA and Lc). According to our hypothesis, the expected motion would imply the FHA to be aligned with Lc (β is null). On the contrary, an abnormal motion would involve a high value of β. In the case α is lower than 5°, the pelvis motion is also considered as abnormal.

Results

70% of the entire population had the expected motion (β<10°), 19% had a β between 10 and 20, 33%of the pathological patients had abnormal motion (β>10 or α<5). More specifically, 27% of the asymptomatic patients have shown abnormal motions, only 14% for the ones suffering from hip troubles against 44% for the ones with spine issues. Note half of these last ones had a small α value.

Discussion

To the authors'knowledge, a quantitative analysis of the SSPK could have been realized for the first time thanks to an accurate 3D reconstruction method. Furthermore, this study shows an abnormal SSPK trend for subjects with spine issues unlike asymptomatic patients or even those with hip diseases. Nevertheless, the major limitation of this study is the number of patients. Though, quantitative assessment of SSPK provides deep insights in SSPK, and future studies could focus on understanding related disorders.

#5816

Pelvic Sagittal Inclination in Supine and Standing After Corrective Long Fusion for Adult Spinal Deformity

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Introduction: The individual pelvic sagittal inclination (PSI) is an issue for cup alignment in total hip arthroplasty (THA). The pelvic position in supine (functional pelvic plane in supine; FPP) has been recommended as the reference to aim an optimal cup alignment by many reports while there are some concerns about the change of PSI in standing. PSI changes in various postures and even in the same posture, aging change it due to spinal degeneration and muscle weakness. The chronological PSI change is larger in standing than that in supine. It is expected that PSI in standing position may improve when spinal long fusion was performed. Therefore, the purpose of this study was to evaluate the change of PSI between pre- and post- corrective long fusion for adult spinal deformity (ASD).

Materials and Methods: Twenty two patients underwent corrective surgery for ASD between May 2014 and April 2018 were the subjects of this study. Twenty one patients are females with the average age of 72 years. There were six cases that underwent THA before spine surgery. The anterior pelvic plane (APP) through the most anterior aspect of the pubic tubercle and bilateral anterior superior iliac spines (ASISs) was used to measure PSI, which was defined as the angle between the APP and the vertical axis on the sagittal plane DRR. In addition, we measured the cup anteversion in two THA cases by using viewer software.

Results: The mean change in the preoperative PSI from supine to standing was 17° posteriorly. The mean change in the supine PSI from pre- to post-operation was 6.1° anteriorly, and that in the standing PSI was 18° anteriorly. The mean change in the postoperative PSI from supine to standing was 5.0° posteriorly. When we measured PSI on standard AP radiographs of the pelvis in five patients who underwent THA before spine fusion, the mean change in postoperative PSI from supine to standing was less than 3°.The mean change in cup anteversion on supine AP radiographs were 3.6°. As we expected, the change in PSI from supine to standing position was reduced by performing corrective surgery.

Discussion and conclusions*:* In this study, our corrective long spine fusion significantly changed PSI particularly in standing. When we looked at the patients who underwent THA before ASD became severe, the mean change of radiographic cup anteversion in supine after corrective long fusion was 3.6°and PSI in standing changed into the direction which reduce posterior impingement and anterior edge loading. Although the change in PSI after corrective spine surgery heavily depends on the spine surgeon's philosophy of correction, corrective spine surgery should have a positive effect on cup alignment in standing and little influence on cup alignment in supine.

#5706

Reduced Bony Hip Range of Motion Associated With ADL Impairment Related to Anteflexion After Rotational Acetabular Osteotomy

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Introduction: Rotational acetabular osteotomy (RAO) is one of the established acetabular redirection osteotomies for DDH. However, the prevalence of ADL impairment after RAO has not been well investigated. Furthermore, the relationship between postoperative bony range of motion (ROM) and ADL impairment has not been well investigated. The purpose of this study were to determine the incidence of ADL impairment related to anteflexion 6month, 1year, and 2 years after RAO, and the relationship between postoperative bony ROM and ADL impairment related to anteflexion at 2 years after RAO.
Methods: We reviewed 26 patients with symptomatic hip dysplasia who underwent RAO in our institution. Inclusion criteria were presence of postoperative CT image and completion of questionnaires obtained prospectively before and 6 months, 1 year, and 2 years postoperatively. There were all female with mean age of 36 years (SD, 8 years) at the time of surgery. We assessed two activities that need deep hip flexion without weight bearing: clipping toenails and putting on and taking off socks. We defined ADL impairment related to anteflexion as difficulty or impossibility of both of two activities above and assessed incidence of this ADL impairment at each time. Using postoperative CT images, lateral and anterior centre edge angles were measured on coronal and sagittal views through the femoral head centre, respectively. Using 3D surface models of the pelvis and femur reconstructed from the postoperative CT images, bony flexion ROM and internal rotation ROM at 90° of flexion were measured. We investigated the relationship between postoperative bony ROMs and ADL impairment related to anteflexion at 2 years after RAO. We also investigated the relationship between ADL impairment related to anteflexion at 2 years after RAO and postoperative femoral head coverage.
Results: The incidence of ADL impairment related to anteflexion was 69% (18/26 hips) at 6 months, 35% (9/26 hips) at 1 year, and 12% (3/26 hips) at 2 years after RAO. Mean bony flexion in 3 subjects with ADL impairment was 97o and that in 23 subjects without ADL impairment was 110o, respectively. (p=0.066). Mean bony internal rotation ROM at 90o flexion in subjects with ADL impairment was significantly less than that without ADL impairment (10o and 37o, respectively, p=0.014). The incidence of ADL impairment was significantly higher in subjects with both bony flexion was 105o or less and bony internal rotation ROM at 90o flexion was 20o or less than that in the remaining subjects (60% (3/5 hips) and 0% (0/21hips), p=0.0038). The femoral head coverage after RAO didn't associate with ADL impairment.
Discussion: Subject may be able to avoid postoperative ADL impairment related to anteflexion, if the subject obtain bony flexion was 105o or more, or bony internal rotation ROM at 90o flexion was 20o or more after RAO. Preoperatively, surgeons may have better plan considering not only femoral head coverage but also postoperative bony ROM to avoid postoperative ADL impairment related to anteflexion.

Figures

Table : The hip morphological parameters and postoperative bony ROM in patients with and without ADL impairment related to anteflexion. (*: $p < 0.05$)

	ADL impairment (+) n=3	ADL impairment (-) n=23	p-value
preoperative morphology			
femoral neck shaft angle (°)	135 (132-138)	132 (121-141)	0.22
femoral anteversion (°)	33 (7-61)	33 (3-66)	0.99
positioning of anterior inferior iliac spine (lower/higher)	1/2	7/16	1
postoperative femoral head coverage			
lateral CEA (°)	36.3 (30.2-39.7)	35.3 (16.4-47.3)	0.80
anterior CEA (°)	62.6 (56-69.8)	56.5 (39.5-77)	0.26
postoperative bony ROM			
bony Flex (°)	97 (90-104)	110 (88-121)	0.066
bony IR @90° flex (°)	10 (0-17)	37 (-10 -65)	0.014 *

Figure 1

Posterior Pelvic Tilt Increases Over Time and Affects Cup Position After Primary Total Hip Arthroplasty

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Introduction: Although pelvic tilt does not significantly change after primary total hip arthroplasty (THA) at a short term, can vary over time due to aging and the possible appearence of sagittal spine disorders. Cup positioning relative to the stem can be influenced due to these changes.

Purpose: We assessed the evolution of pelvic tilt and cup position after THA for a minimum follow-up of five years and the possible appearence of complications.

Materials and methods: 47 patients underwent same single THA between 2008 and 2012. All were diagnosed with primary osteoarthritis and their mean age was 70.2 years (range, 63 to 75). There were 28 male patients, 19 had a contralateral THA, 17 were studied for lumbar pathology and three were operated for lumbo-sacral fusion. Radiological analysis included sacro-femoral-pubic and acetabular abduction angles on the anteroposterior pelvic view; and cup anteversion angle on the lateral cross-table hip view according to Woo and Morrey. All assessments were done pre-operatively and at 6 weeks, one, two and five years post-operatively. Three measurements were recorded and mean was obtained at all intervals All radiographs were evaluated by the same author, who was not involved in surgery.

Results: There were four dislocations: one early and two contralateral dislocations which were solved wiith closed reduction, and one late recurrent dislocation five years after surgery which required cup revision. No other revision surgeries were performed. Mean sacro-femoral pubic angle decreased at all intervals from 60.6º preoperatively, to 60.0º at one year and 58 .8 º at five years. This decrease was more significant in female, 63.3º preoperatively to 59.3º, than in male patients, 58.7º to 58.3º at five years. Mean acetabular abduction angle increased from 47.3º at 6 weeks to 48.2º at five years. Mean cup anteversion increased from 24.3º at 6 weeks to 26.4º at one year and 34.3º at five years.

Conclusions: Posterior pelvic tilt increased with aging over time, particularly in women. These changes increased cup inclination and anteversion which may result in more dislocations after primary THA

A New Quantitative Load Balancing Sensor for Reverse Total Shoulder Arthroplasty

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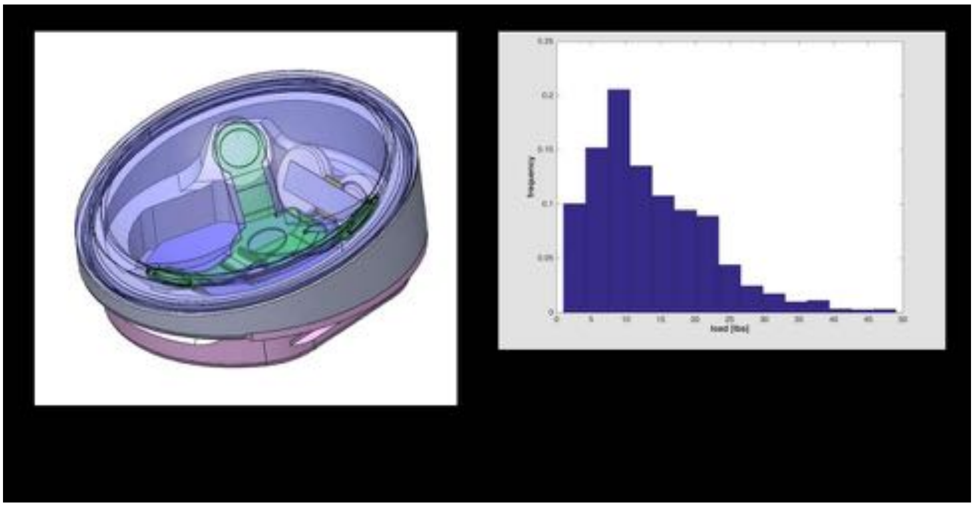
Introduction & Aims – Over the last decade, sensor technology has proven its benefits in total knee arthroplasty, allowing the quantitative assessment of tension in the medial and lateral compartment of the tibiofemoral joint through the range of motion (VERASENSE, OrthoSensor Inc, FL, USA). In reversal total shoulder arthroplasty, it is well understood that stability is primarily controlled by the active and passive structures surrounding the articulating surfaces. At current, assessing the tension in these stabilizing structures remains however highly subjective and relies on the surgeons' feel and experience. In an attempt to quantify this feel and address instability as a dominant cause for revision surgery, this paper introduces an intra-articular load sensor for reverse total shoulder arthroplasty (RTSA).

Method – Using the capacitive load sensing technology embedded in instrumented tibial trays, a wireless, instrumented humeral trial has been developed. The wireless communication enables real-time display of the three-dimensional load vector and load magnitude in the glenohumeral joint during component trialing in RTSA. In an in-vitro setting, this sensor was used in two reverse total shoulder arthroplasties. The resulting load vectors were captured through the range of motion while the joint was artificially tightened by adding shims to the humeral tray.

Results – For both shoulder specimens, the newly developed sensor provided insight in the load magnitude and characteristics through the range of motion. In neutral rotation and under a condition assessed as neither too tight nor too loose, glenohumeral loads in the range of 10-30lbs were observed. As expected, with increasing shim thickness these intra-articular load magnitudes increased. Assessing the load variations through the range of motion, high peak forces of up to 120 lbs were observed near the limits of the range of motion, most pronounced during external humeral rotation.

Conclusions – In conclusion, this paper presents an intra-articular load sensor that can be used during the trialing phase in reverse total shoulder arthroplasty. A first series of cadaveric experiments provided evidence of realistic load ranges and load characteristics with respect to the end of the range of motion. Currently, effort is undertaken to develop a biomechanically validated load range that can serve as a target in surgery.

Figures


0.25
0.2
0.15
0.1
0.05
0
frequency
0
5
10
15
20
25
30
35
40
45
50
load [lbs]

[Figure 1](#)

Collection of Innovative Patient-Reported Outcome Measures Using a Digital Platform. Interim Results From a Feasibility Study With TKA Patients.

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Introduction Acquisition, interpretation and dissemination of clinical data is important to optimize clinical outcomes and minimize risk of complications in total joint arthroplasty. Introduction of new requirements associated with MedDev Rev 4 and the Medical Device Regulations (MDR) also places increased emphasis on the need to generate relevant clinical data to provide evidence on safety, efficacy and patient benefit. A digital platform to enhance patient engagement and collect patient-reported outcome measurements (PROMs) was recently adapted for TKA patients to address the need for more patient-centered data and information.

Methods The digital platform consists of a patient mobile application (app) and a clinician dashboard. The app collects a variety of PROMs, including some based on the innovative Patient-Reported Outcome Information System (PROMIS®). The electronic administration of the PROMIS® questionnaires (computer-adaptive tests (CATs)) reduces the survey burden on patients and staff, as the questions presented are based upon the respondent's previous answers. Additional features of the digital platform include staff-patient messaging, educational articles and reminders for medications and other health-related activities.

Fifty-two patients (mean age 62.8 years, 56% females) scheduled for TKA were enrolled from 5 UK sites and 1 US site between January 12, 2018 and April 19, 2018. These patients form part of a longer clinical study on the usability of this digital platform for collecting responses to PROMIS® questionnaires. This work reports upon the results from this initial cohort of patients in terms of patient engagement and PROMIS CAT survey completion. Four PROMIS domains were measured: physical function, depression, pain interference and pain behaviour. Depending on their post-operative phase, a subset of patients additionally responded to surveys to assess the ease-of-use of the app (n=22) and the successful use of the information from the app during their recovery (n=13), on a scale of 1-10.

Results The patients demonstrated willingness to engage regularly with the platform. On average, 83% of all enrolled patients engaged with the app at least once per week. The weekly engagement remained high throughout the post-operative period (Figure 1). Patients completed 77% of all PROMIS CAT surveys during the time period, with similar survey completion rates regardless of the PROMIS CAT domain in question (Figure 2). Patients who completed the user experience questions responded with a mean score of 8.9/10 for the ease-of-use of the app (n=22). Nine out of 13 patients reported having been successful or very successful (7/10 or higher) at using the information from the app during their recovery.

Conclusions The results collected so far show high patient engagement and satisfaction with the app. High adherence to the PROMIS CAT surveys further supports the potential of the app to collect large volumes of PROMs in a straightforward and well-accepted way.

Figures

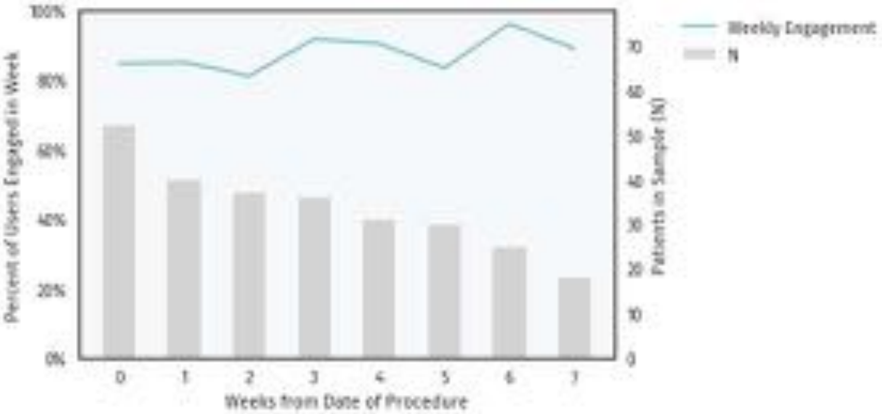

Figure 1

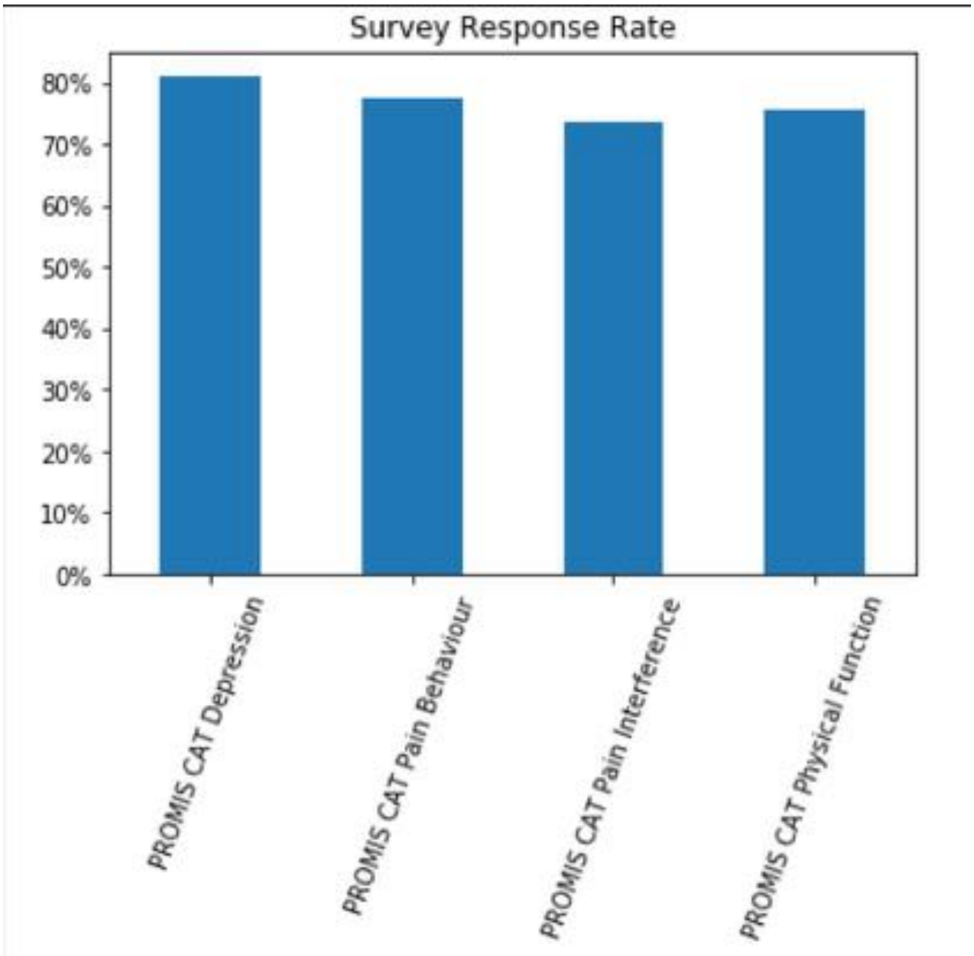

Figure 2

#5655

Smart Treatment for the Surface of Titanium Implants: Development of Multifunctional Surfaces

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In order to improve fast osseointegration, to modulate inflammatory response and to avoid biofilm formation, several attempts of surface modifications of titanium alloy in term of surface topography and chemistry have been performed over years, but this is still an open issue.

In our research work, a patented chemical treatment [1,2] was developed and tailored to improve fast osseointegration and to allow further surface functionalization in order to get a multifunctional surface.

After the chemical treatment, Ti6Al4V shows a micro and nano-textured surface oxide layer with high density of hydroxyls groups, as summarized Figure 1: it is able to induce apatite precipitation (during soaking in Simulated Body Fluid), high wettability by blood, specific protein adsorption, positive osteoblast response and surface mechanical resistance to implantation friction.

Hydroxyl groups exposed by the treated surface also allow binding natural biomolecules such as polyphenols, which can further improve the rate and quality of osseointegration by adding anti-inflammatory, antibacterial and antitumoral effects suitable for implants in critical situations [3,4] (Figure 2). Polyphenols have the further added value of being a low cost and eco-sustainable product, extractable from byproducts of wine and food industry.

On the chemically treated and functionalized samples, the surface characterization was performed using Folin&Ciocalteu test, fluorescence microscopy and XPS analysis in order to check the presence and activity of the grafted biomolecules (polyphenols from red grape pomace and green tea leaves). Cell tests were performed with Kusa A-1 cells highlighting the ability of polyphenols to improve osteoblasts differentiation and deposition of mineralized extracellular matrix.

Surface functionalization can also be performed with chitin derived biomolecules to reduce inflammation.

With the purpose of obtaining the antibacterial effect, during the chemical treatment a silver precursor can also be added to obtain *in situ* reduced silver nanoparticles embedded in the nano-structured oxide layer [5]. The samples containing nanoparticles on the surface were characterized by means of TEM and FESEM observation highlighting the presence of well distributed and small-sized nanoparticles on the surface and through the thickness of the oxide layer. A long-lasting release in water was observed up to 14 days and antibacterial tests on *Staphylococcus aureus* showed the ability of the surface to reduce bacteria viability avoiding biofilm formation (Figure 3).

The results showed that the patented chemical treatment can improve the response of osteoblasts to titanium alloy implants, but is also a promising way to obtain multifunctional surfaces with antibacterial, antioxidant, anti-inflammatory and antitumoral properties that can be the future of orthopedic implants.

GLOBAL (funded by MAECI – Italy) and NAT4MORE (funded by EC – M.ERA-NET) projects are acknowledged for supporting different research activities.

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Figures

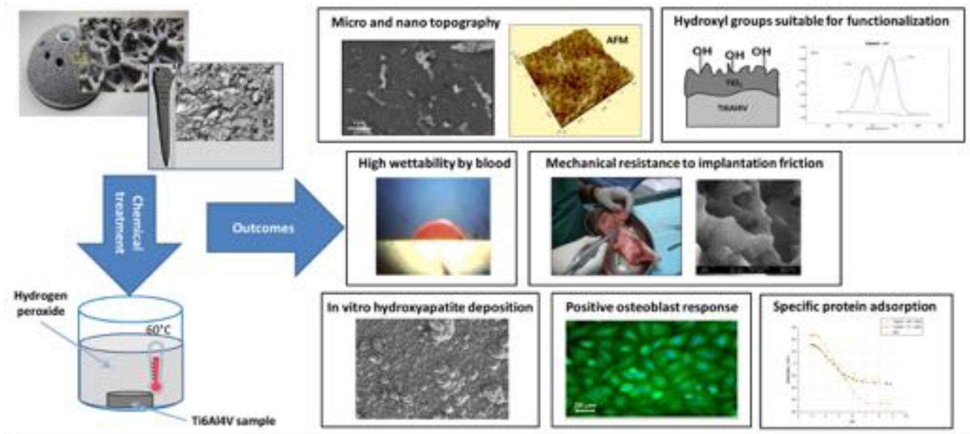

Figure 1

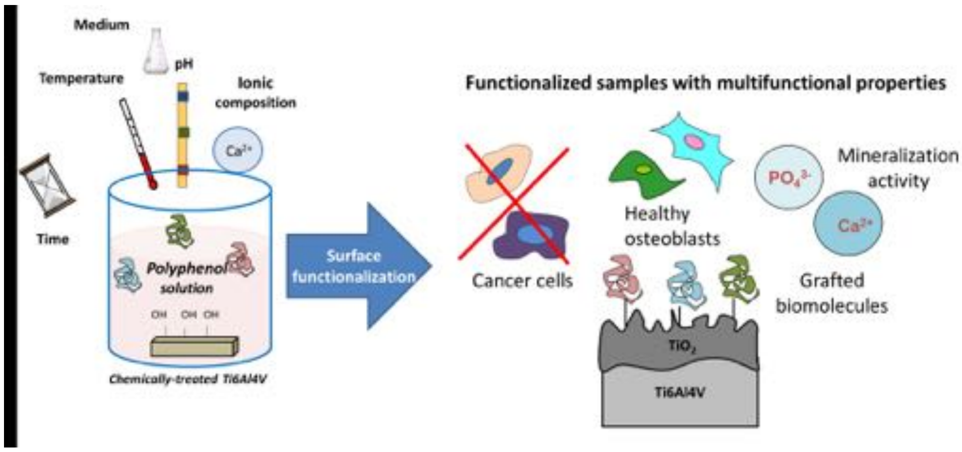

Figure 2

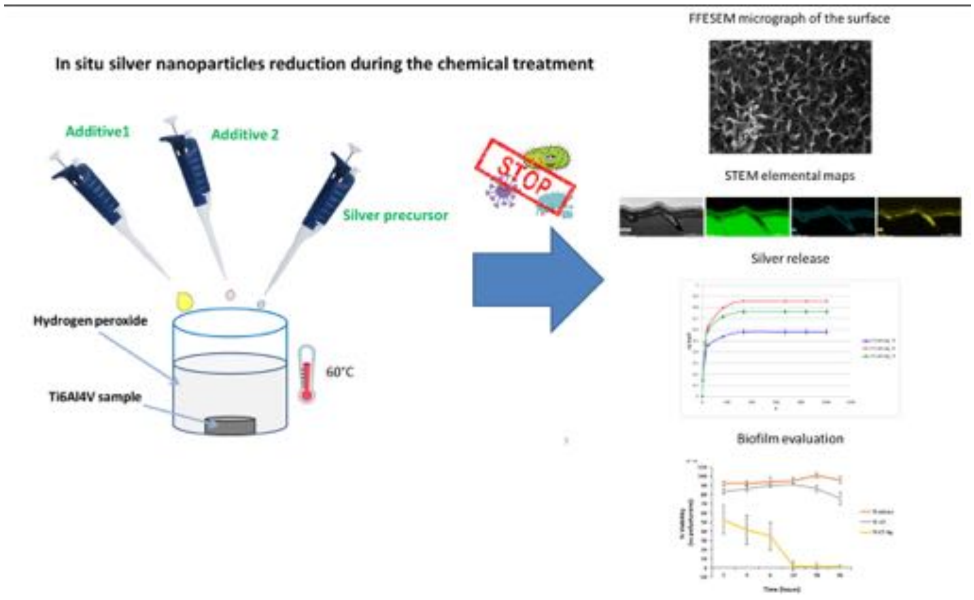
FFESEM micrograph of the surface
In situ silver nanoparticles reduction during the chemical treatment
Additive1
Additive 2
Silver precursor
STOP
STEM elemental maps
Silver release
Hydrogen peroxide
60°C
Ti6Al4V sample
Biofilm evaluation

Figure 3

Avoiding Intraoperative Fractures in Total Hip Arthroplasty Using a Practical Vibrational Analysis Technique During Bone Preparation

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Isaiah Adekanmbi - Depuy Synthes - Leeds, United Kingdom
Chris Hunt - DePuy Synthes Joint reconstruction - Leeds, United Kingdom
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Introduction

Intraoperative periprosthetic femoral fracture is the third most frequent cause of revision of primary Total Hip Arthroplasty (THA) [1]. Anecdotally, surgeons reduce the risk of fracture by carefully listening to the change in pitch during impaction. Sensor-assisted methods to avoid femoral fracture during THA have been explored by monitoring audible sound [2], acoustic emission [3], and vibration from piezoelectric sensors [4]; however, these suffered from poor signal to noise quality or required an extra step using an artificially controlled vibrational input. The purpose of this investigation, therefore, was to explore a reliable and robust method that monitors vibration signals during THA without disrupting surgical workflow. We hypothesised that a piezoelectric accelerometer attached distally could directly detect a change in the frequency response during impaction of a fractured Sawbones femur.

Methods

Two identical Sawbone femurs (SKU1121-Medium) were prepared using standard surgical technique for the Summit Hip system (DePuy Synthes) progressing from size 1-4. A fracture (Type-A2-Vancouver Classification [1]) was then simulated in one of the Sawbones by further advancing the size 4 broach after seating state until a periprosthetic fracture occurred at the lesser trochanter (Figure1-a). An accelerometer (PCB-M353B18) was secured to the medial epicondyle of femurs using adhesive tape (Figure1-b). The size 4 broach was then reinserted into a firm-seated condition and 3 sets of 10 impactions were performed while holding the femur in hand whilst standardizing the strike location, orientation, and force (Figure1-c). Data (40kHz) was postprocessed using LabVIEW (Figure1-d) and a spectrogram was created for qualitative comparison. Fast Fourier Transform (FFT) was used for each strike where the amplitudes were normalized individually according to their own maximum peak values. The areas under the FFT curve were compared for the intact and fractured Sawbones.

Results

The resonance frequency of both groups was between 1-2kHz (Figure2-a and Figure2-b). There appears to be a difference, however, between the groups at frequencies great than 4kHz, which corresponds to a statistical difference ($p<0.05$) in the areas under the FFT curves (Figure2-c).

Discussion and conclusion

We have demonstrated a new method to quantify vibration during impaction that minimises interruption to surgical workflow. The observed resonance frequency was between 1kHz-2kHz, which agrees with previous findings [4], [5]. Furthermore, our results suggest that a new parameter, area under the FFT curve, may be helpful in identifying fracture. While potentially useful, future work is required to elucidate the physical interpretation; demonstrate robustness to variability of strike location, orientation, and force; as well as introduce real-time feedback that could allow surgeons to anticipate and prevent fracture.

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Antibacterial Properties of Bupivacaine-Loaded UHMWPE

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Introduction. Pain after total joint replacement (TJR) is addressed mainly using systemic opioids with associated risks, such as drug-related toxicity, overdose and addiction. Another important complication of TJR is periprosthetic joint infection (PJI). Although its prevalence is low (1-2%), the mortality rate associated with the recurrence of these infections can be up to 25%. Our long-term goal is to address post-arthroplasty pain locally while minimizing the risk of PJI by delivering therapeutics from the ultrahigh molecular weight polyethylene (UHMWPE) bearing surface. The commonly-used analgesic bupivacaine was shown to possess some antimicrobial activity against *Staphylococcus aureus* and *Staphylococcus epidermidis* [2] – two strains that commonly cause PJI [3]. Here, we investigate the antimicrobial properties of bupivacaine released from bupivacaine-loaded UHMWPE.

Materials and Methods. Medical grade UHMWPE loaded with different bupivacaine content (10, 15, 20 wt%) was prepared by blending UHMWPE powder with Buipivacaine Hydrochloride powder and compression molding the powder blend into 3 mm thick samples. Following consolidation, samples were sectioned into 3mm x 5mm x 20 mm strips and bupivacaine release measurements were performed by placing each strip in 1.7 ml deionized water at room temperature for 2 months, replacing the water with fresh deionized water at each measurement time point. The elution of bupivacaine was quantified by high-performance liquid chromatography (HPLC). Liquid chromatography – mass spectroscopy (LCMS) was used to assess potential degradation of the drug molecules during sample preparation. The following antibacterial studies were performed according to the Clinical & Laboratory Standards Institute (CLSI) protocols. Agar diffusion test was used for the evaluation of the antimicrobial activity. Furthermore, antibacterial effect against planktonic bacteria and antibiofilm activity of the drug-impregnated samples were assessed in the model experiments with *S. aureus* and *S. epidermidis*.

Results and Discussion. The obtained LCMS results showed that the proposed consolidation protocol did not cause bupivacaine degradation. The release rate of bupivacaine from UHMWPE was proportional to the initial loading in a non-linear fashion. Sustained release of the drug from UHMWPE matrix was shown for up to 2 months (Fig. 1). Bupivacaine-loaded samples demonstrated dose-dependent antimicrobial properties against *S. aureus* and *S. epidermidis* (Fig. 2). Modified samples possessed short-term anti-colonization properties: bacterial adherence to the bupivacaine-loaded surfaces was significantly inhibited compared to that on UHMWPE without drug (Fig. 3).

Significance. To the best of our knowledge, this is the first study showing antimicrobial properties of analgesic-loaded UHMWPE bearing surface. Demonstrated antibacterial properties of the bupivacaine-impregnated samples demonstrated that the multifunctional approach proposed in this study may be feasible to address post-operative pain and PJI prophylactically.

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Figures

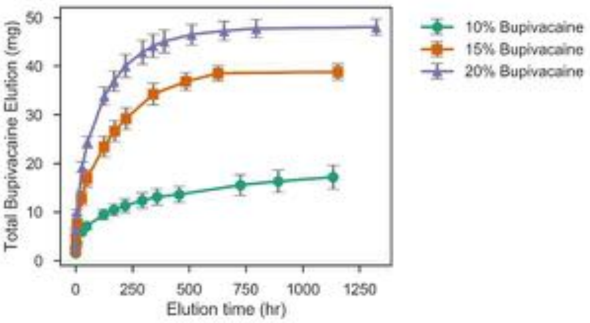

Figure 1. Bupivacaine release kinetics from UHMWPE prepared with different drug content.

Figure 1

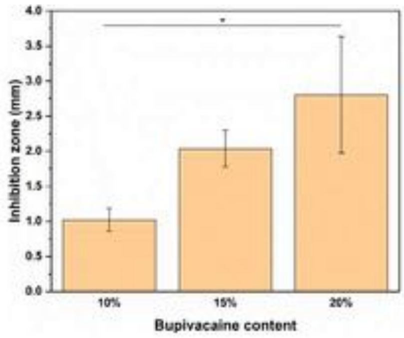

Figure 2. Inhibition zones for *S. aureus* around UHMWPE loaded with different bupivacaine content. Asterisks represent significant difference between samples as calculated by ANOVA ($p = 0.004$, $n = 4$)

Figure 2

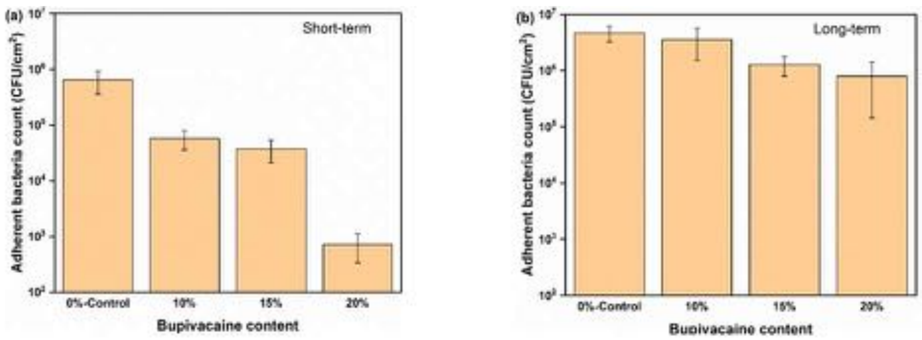

Figure 3. Short- (7.5 hours) and long-term (24 hours) anti-colonization effect of UHMWPE loaded with different bupivacaine content against *S. aureus*.

Figure 3

Gentamicin Sulfate Eluting UHMWPE Spacer for Two-Stage Revision

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Introduction. Infection continues to be a major challenge of total joint surgery [1]. One method often used to treat infected patients is a two-stage revision surgery, but it has mixed outcomes [2]. The first step is a temporary implantation of an antibiotic-eluting bone cement spacer, and the second is a reimplantation of a permanent device. Like bone cement, ultra-high molecular weight polyethylene (UHMWPE) can also be used as a carrier for antibiotics. Recently, we demonstrated that vancomycin and rifampin can be successfully delivered from UHMWPE implants at therapeutic levels to eradicate *Staphylococcus aureus* biofilm in a lupine animal model [3]. There are regulatory challenges in translating these types of combination devices into clinical use. One approach is to first seek clearance for a temporary UHMWPE spacer containing gentamicin sulfate (GS/PE). In this study, we explored the effect of GS content in UHMWPE on GS elution rate and antimicrobial activity against methicillin-sensitive S. aureus (MSSA). We also assessed the effect of spacer fabrication on the activity of GS.

Materials and Methods. We prepared and consolidated GS/PE blends in varying concentrations. We eluted test strips in PBS at body temperature for up to six months and quantified eluted GS content using liquid chromatography – mass spectrometry (LCMS). We assessed any detectable changes in activity of eluted GS caused by spacer fabrication by screening m/z peaks of GS isomers in mass spectra obtained from LC-MS. We measured the antibacterial activity of the obtained samples in vitro against various concentrations of MSSA (10^3-10^6 CFU/ml). Furthermore, we quantified the probability of bacterial colonization of GS/PE compared to GS-containing bone cement (GS/BC).

Results and Discussion. Gentamicin sulfate activity was not compromised by the elevated temperature and pressure used during spacer fabrication. Elution rate of GS increased with increasing GS content in the blends studied (Figure 1). At comparable elution rates, the GS/PE was either equivalent or better in terms of antibacterial and anticolonization properties when compared with GS-containing bone cement (Figure 2).

Significance. GS/PE is a promising material for temporary spacers that may provide an alternative to antibiotic-eluting bone cement.

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Figures

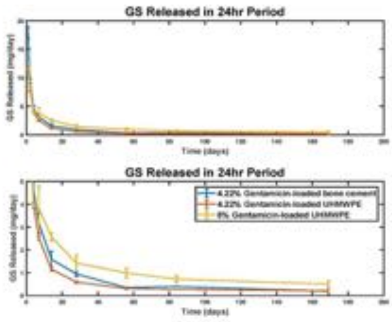

Figure 1. Daily gentamicin sulfate elution rates of GS/PE (4.22 % & 8 %) and GS/BC for a 6-month period. Rates are calculated using surface area of XL size total knee spacer components.

Figure 1

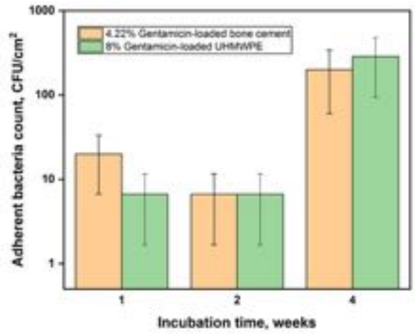

Figure 2. Anti-colonization activity of GS/PE and GS/BC against 10^6 CFU/ml *S. aureus*. Prior to the measurements, samples were incubated in PBS at 37°C for 1, 2, and 4 weeks.

Figure 2

#5530

The Reliability of Synovasure (Alfa Defensin-1 Assay) in Intra-Operative Diagnosis of Prosthetic Joint Infection

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ABSTRACT

Introduction

The intra-operative diagnosis of Prosthetic Joint Infection (PJI) is a dilemma requiring intra-operative sampling of suspicious tissues for frozen section, deep tissue culture and histopathology to secure a diagnosis. Alfa defensin-1 testing has been introduced as a quick and reliable test for confirming or ruling out PJI. This study aims to assess its intra-operative reliability compared to the standard tests.

Methods

Twenty patients who underwent revision hip and knee arthroplasty surgery were included. Patients joint aspirate was tested intra-operatively with the Synovasure kit, which takes approximately ten minutes for a result. Our standard protocol of collecting 5 deep tissue samples for culture and one sample for histopathology was followed. Results for Alfa defensin-1 test were then compared with final culture and histopathology results in all these patients.

Results

Our results show an excellent correlation with the final deep tissue cultures and histopathology outcomes. Literature reports frozen section to have low (58-73%) sensitivity but high (96%) specificity.

Conclusions

Alfa defensin-1 test is easy, quick and efficient; results were available immediately intra-operatively. Cryosection is time consuming with samples shipped to the reference laboratory at times resulting in intra-operative delays. In our practice Alfa defensin-1 test certainly will replace frozen section for intra-operative testing.

KEYWORDS: Prosthetic Joint Infection (PJI),Alfa defensin-1 kit, synovial fluid biomarkers

#5552

Is Robotic-Arm Assisted Unicompartmental Knee Arthroplasty Associated With Reduced Postoperative Pain and Early Restoration of Function?

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Objectives:

The primary objective of this study was to compare postoperative pain between patients undergoing conventional jig-based UKA versus robotic-arm assisted UKA. Secondary objectives were to determine differences between these two treatment groups relating to opiate analgesia consumption, early functional outcomes, time to hospital discharge, and postoperative complications.

Methods:

This prospective cohort study included 146 patients with symptomatic medial compartment knee osteoarthritis undergoing primary UKA performed by a single surgeon. This included 73 consecutive patients undergoing conventional jig-based UKA followed by 73 consecutive patients receiving robotic-arm assisted UKA. All surgical procedures were performed using the standard medial parapatellar approach for UKA, and all patients underwent the same postoperative rehabilitation programme. Postoperative pain scores on the numerical rating scale and opiate analgesia consumption were recorded until discharge. Time to attainment of early functional outcomes, hospital discharge, and postoperative complications were recorded by independent observers.

Results:

Robotic-arm assisted UKA was associated with reduced postoperative pain ($P<0.001$), decreased opiate analgesia requirements ($p<0.001$), shorter time to straight leg raise ($p<0.001$), decreased number of physiotherapy sessions ($p<0.001$), and increased maximum knee flexion at discharge ($p<0.001$) compared to conventional jig-based UKA (Figures 1-2). Mean time to hospital discharge was reduced in robotic UKA compared to conventional UKA (42.5 ± 5.9 hours vs 71.1 ± 14.6 hours respectively, $p<0.001$)(Figure 3). There was no difference in postoperative complications between the two groups during the 30-day follow-up period.

Conclusion:

Robotic-arm assisted UKA is associated with decreased postoperative pain, reduced opiate analgesia requirements, improved early functional outcomes, and shorter time to hospital discharge compared to conventional jig-based UKA.

Clinical relevance:

Robotic-arm assisted surgery is associated with reduced postoperative pain, faster inpatient rehabilitation, and reduced length of hospital stay following UKA.

Figures

Figure 1: Boxplot showing pain scores on the numerical rating scale in patients undergoing conventional jig-based UKA versus robotic-arm assisted UKA

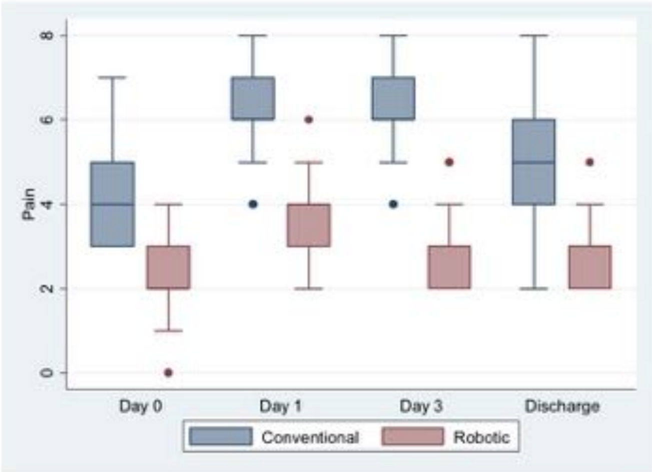

Figure 1

Figure 2: Boxplot showing pain opiate analgesia consumption in patients undergoing conventional jig-based UKA versus robotic-arm assisted UKA

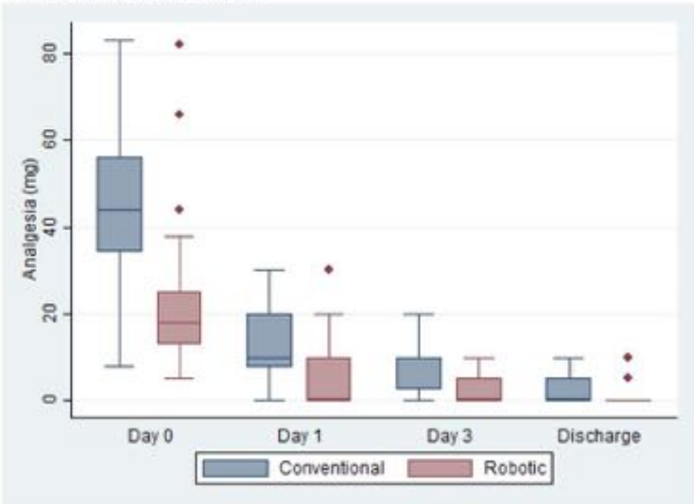

Figure 2

Figure 3: Boxplot showing time to discharge in patients undergoing conventional jig-based UKA versus robotic-arm assisted UKA

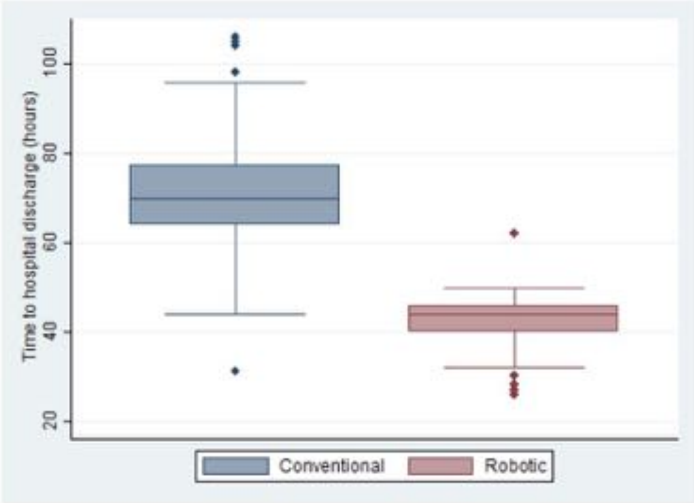

Figure 3

#5684

Kinematic Assessment of Anatomical Compartment Specific Partial Knee Arthroplasty

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Introduction

Partial knee arthroplasty (PKA) has demonstrated the potential to improve patient satisfaction over total knee arthroplasty [Zuiderbaan et al, JBJS*Br* 2016]. It is however perceived as a more challenging procedure that requires precise adaptation to the complex mechanics of the knee. A recently developed PKA system aims to address these challenges by anatomical, compartment specific shapes and fine-tuned mechanical instrumentation. We investigated how closely this PKA system replicates the balance and kinematics of the intact knee.

Material and Methods

Eight post-mortem human knee specimens (age: 55±11 years, BMI: 23±5, 4 male, 4 female) underwent full leg CT scanning and comprehensive robotic (KUKA KR140 comp) assessments of tibiofemoral and patellofemoral kinematics. Specimens were tested in the intact state and after fixed bearing medial PKA. Implantations were performed by two experienced surgeons.

Assessments included laxity testing (anterior-posterior: ±100 N, medial-lateral: ±100 N, internal-external: ±3 Nm, varus-valgus: ±12 Nm) under 2 compressive loads (44 N, 500 N) at 7 flexion angles and simulations of level walking, lunge and stair descent based on in-vivo loading profiles. Kinematics were tracked robotically and optically (OptiTrack) and represented by the femoral flexion facet center (FFC) motions. Similarity between intact and operated curves was expressed by the root mean square of deviations (RMSD) along the curves. Group data were summarized by average and standard deviation and compared using the paired Student's T-test ($\alpha = 0.05$).

Results

During the varus-valgus balancing assessment the medial and lateral opening of the PKAs closely resembled the intact openings across the full arch of flexion (Figure 1), with RMSD values of 1.0±0.5 mm and 0.4±0.2 mm respectively. The medial opening was nearly constant across flexion, its average was not statistically different between intact (3.8±1.0 mm) and PKA (4.0±1.1 mm) (p=0.49).

Antero-posterior envelope of motion assessments revealed a close match between the intact and PKA group for both compression levels (Figure 2). Net rollback was not statistically different, either under low compression (intact: 10.9±1.5 mm, PKA: 10.7±1.2, p=0.64) or under high compression (intact: 13.2±2.3 mm, PKA: 13.0±1.6 mm, p=0.77). Similarly, average laxity was not statistically different, either under low (intact: 7.7±3.2 mm, PKA: 8.6±2.5 mm, p=0.09) or under high (intact: 7.2±2.6 mm, PKA: 7.8±2.2 mm, p=0.08) compression.

Activities of daily living (example: Figure 3, for lunge) exhibited a close match in the anterior-posterior motion profile of the medial condyle (RMSD: lunge: 2.2±1.0 mm, level walking: 2.4±0.9 mm, stair descent: 2.2±0.6 mm) and lateral condyle (RMSD: lunge: 2.4±1.4 mm, level walking: 2.2±1.4 mm, stair descent: 2.7±2.0 mm). Patellar medial-lateral tilt (RMSD: 3.4±3.8°) and medial-lateral shift (RMDS: 1.5±0.6 mm) during knee flexion matched closely between groups.

Conclusion

Throughout the comprehensive functional assessments the investigated PKA system behaved nearly identical to the intact knee. The small residuals are unlikely to have a clinical effect; further studies are necessary as cadaveric studies are not necessarily indicative of clinical results. We conclude that PKA with anatomical, compartment specific shapes and fine-tuned mechanical instrumentation can be adapted precisely to the complex mechanics of the knee and replicates intact knee balance and kinematics very closely.

Figures

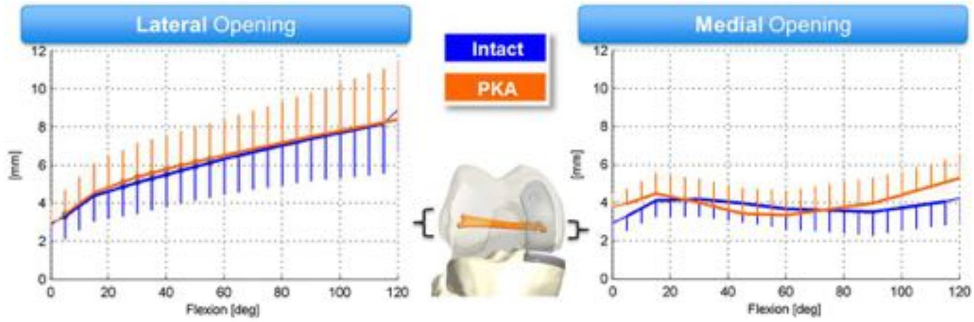

Figure 1: Compartmental opening resulting from a varus-valgus loading of ±12 Nm.
Open circles indicate statistical significant differences in all figures.
Figure 1

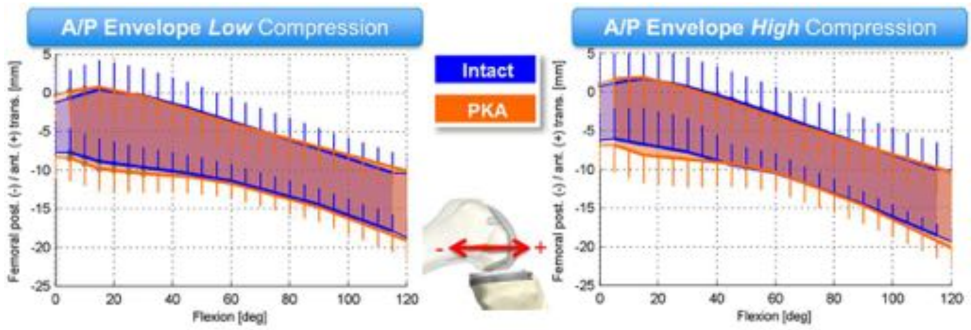

Figure 2: Anterior-posterior envelope of motion resulting from an A/P loading of ±100 N
Figure 2

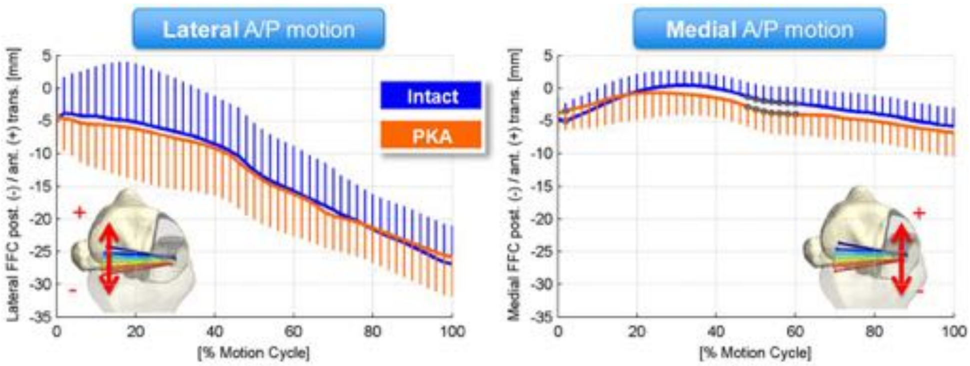

Figure 3: Compartmental anterior-posterior motions during the lunge activity.
Figure 3

#5592

Indication for Medial Unicompartmental Knee Arthroplasty in ACL-Deficient Knees: In Vivo Kinematic Evaluation Using a Moving Fluoroscope

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ABSTRACT

BACKGROUND:

UKA is functionally superior to TKA, with kinematics similar to native knees, nevertheless, UKA implants are used in less than 10% of cases. While advantages of UKA are recognized, ACL-deficiency is generally considered a contraindication. The hypothesis of this study was that fix bearing UKA in ACL-deficient knees, with appropriate adaptation of implant placement, would result in similar kinematic trends to conventional UKA with an intact ACL.

METHODS:

Ten conventional UKA patients were compared to eight patients with the same implant but a deficient ACL. A 50% tibial slope reduction was applied to compensate for instability resulting from the deficient ACL. Knee kinematics were evaluated using a moving fluoroscope allowing to track the knee joint during deep knee bend, level walking, ramp descent and stair descent. The results were further compared to six TKA patients.

RESULTS:

During standing, a posterior shift of the femur was observed for the ACL-deficient UKA patients compared to conventional UKA patients. This posterior shift was also present during the first 25% of deep knee bend. Most parameters revealed no difference in range of motion across all activities between the two UKA groups. This is in contrast to TKA patients showing different motion trends and decreased range of motion.

CONCLUSIONS:

Despite the posterior femoral shift due to ACL-deficiency, both UKA groups showed similar kinematic trends, indicating that posterior tibial slope reduction can partially compensate for ACL function. This confirmed our hypothesis that fix bearing UKA can be a viable treatment option for selected ACL-deficient patients.

KEYWORDS

partial knee implants; UKA; ACL-deficient UKA; in vivo kinematics; moving fluoroscope

#6071

In Vitro Biomechanics of UKA and UKA Combined With ACL Reconstruction

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Introduction
Unicompartmental knee arthroplasty (UKA) currently experiences increased popularity. It is usually assumed that UKA shows kinematic features closer to the natural knee than total knee arthroplasty (TKA). Especially in younger patients more natural knee function and faster recovery have helped to increase the popularity of UKA. Another leading reason for the popularity of UKA is the ability to preserve the remaining healthy tissues in the knee, which is not always possible in TKA. Many biomechanical questions remain, however, with respect to this type of replacement.
25% of knees with medial compartment osteoarthritis also have a deficient anterior cruciate ligament [1]. In current clinical practice, medial UKA would be contraindicated in these patients. Our hypothesis is that kinematics after UKA in combination with ACL reconstruction should allow to restore joint function close to the native knee joint. This is clinically relevant, because functional benefits for medial UKA should especially be attractive to the young and active patient.

Materials and Methods
Six fresh frozen full leg cadaver specimens were prepared to be mounted in a kinematic rig (Figure 1) with six degrees of freedom for the knee joint. Three motion patterns were applied: passive flexion-extension, open chain extension, and squatting. These motion patterns were performed in four situations for each specimen: with the native knee; after implantation of a medial UKA (Figure 2); next after cutting the ACL and finally after reconstruction of the ACL. During the loaded motions, quadriceps and hamstrings muscle forces were applied. Infrared cameras continuously recorded the trajectories of marker frames rigidly attached to femur, tibia and patella. Prior computer tomography allowed identification of coordinate frames of the bones and calculations of anatomical rotations and translations. Strains in the collateral ligaments were calculated from insertion site distances.

Results
Knee kinematics and collateral ligament strains were quite close to the native situation after both UKA and ACL reconstruction for all motor tasks. Nevertheless, some statistically significant differences were detected, which may be relevant clinically and biomechanically. In general, insertion of a UKA led to a knee joint which was somewhat less adducted (Figure 3), with a medial femoral condyle located slightly higher, confirming previously published findings [2] . These effects were slightly reduced both after cutting as well as after reconstructing the ACL. The joint became somewhat less stable in the AP direction after insertion of a UKA and this instability persisted not only after cutting but even after reconstructing the ACL.

References
[1] Hodge W.A. et al, Patterns of osteoarthritis in Arabian and American knees. J Arthroplasty. 2009 Apr; 24(3):448-53.

[2] Heyse, T. J., et al. "UKA closely preserves natural knee kinematics in vitro." Knee

surgery, sports traumatology, arthroscopy 22.8 (2014): 1902-1910.

Figures

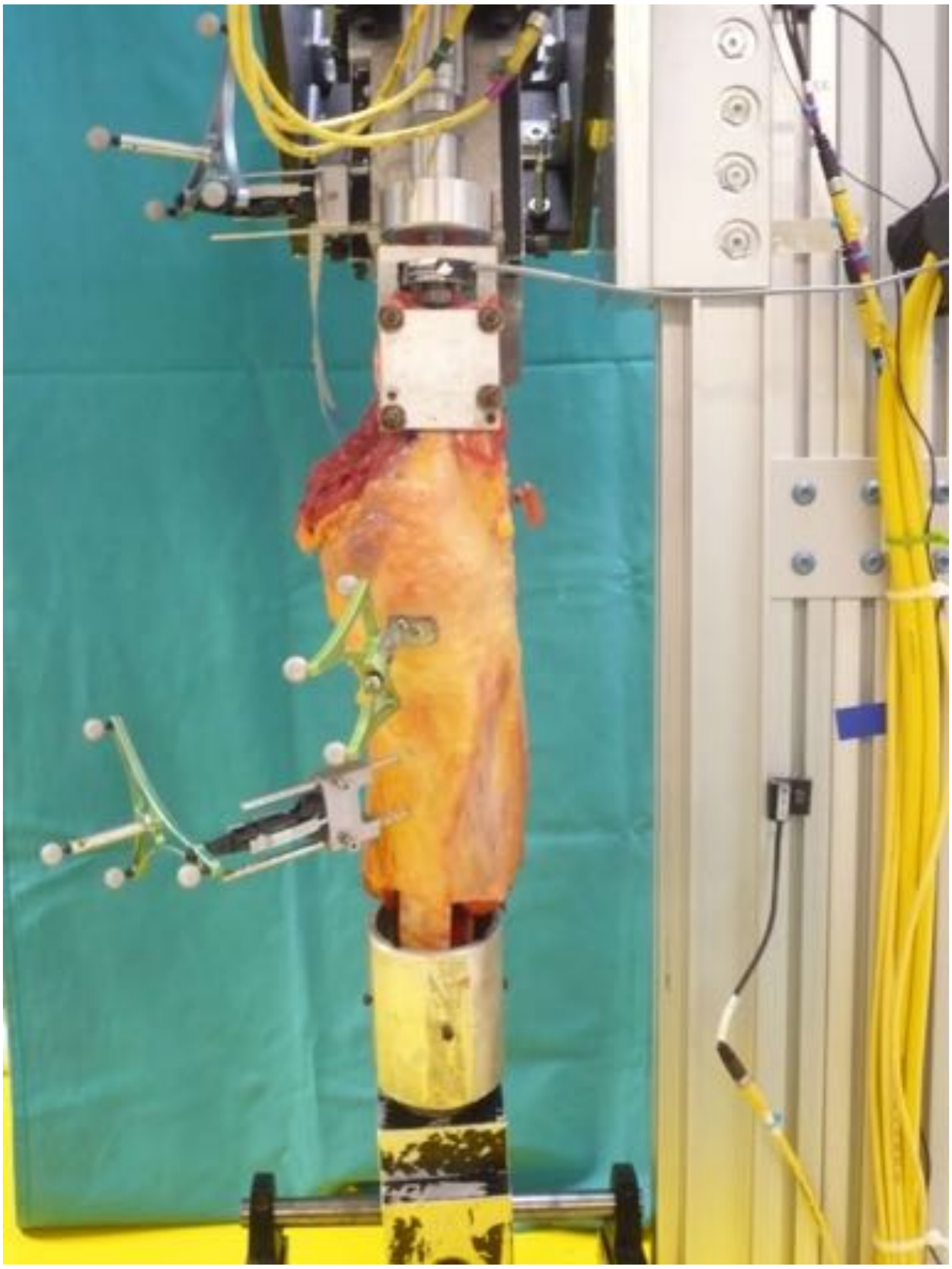

Figure 1

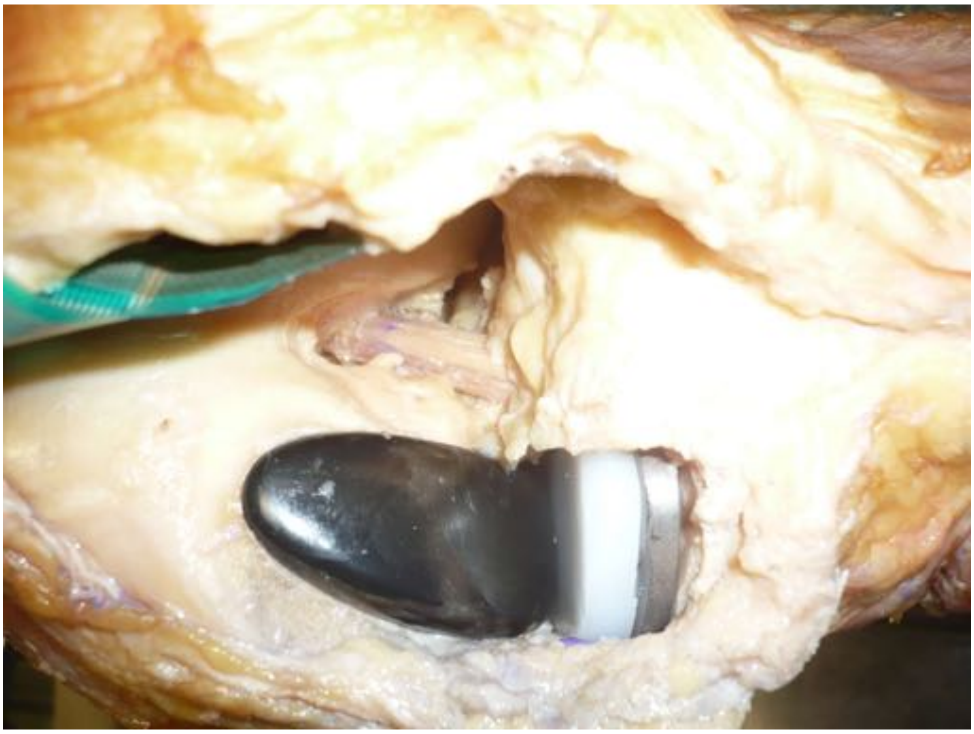

Figure 2

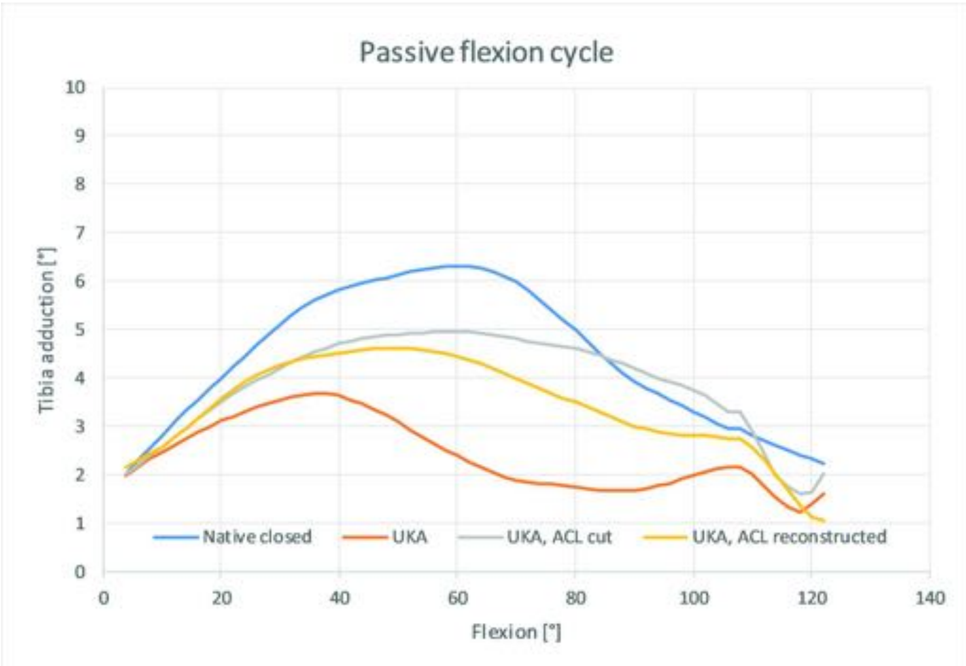

Figure 3

#5853

Effect of Extra-Articular Deformities on Limb Alignment After Mobile-Bearing Unicompartmental Knee Arthroplasty

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Aims The aims of this retrospective study were to determine the incidence of extra-articular deformities (EADs), and determine their effect on postoperative alignment in knees undergoing mobile-bearing, medial unicompartmental knee arthroplasty (UKA).

Patients and Methods Limb mechanical alignment (hip-knee-ankle angle), coronal bowing of the femoral shaft and proximal tibia vara or medial proximal tibial angle (MPTA) were measured on standing, full-length hip-to-ankle radiographs of 162 patients who underwent 200 mobile-bearing, medial UKAs

Results Incidence of EAD was 7.5% for coronal femoral bowing of >5°, 67% for proximal tibia vara of >3° (MPTA<87°) and 24.5% for proximal tibia vara of >6° (MPTA<84°). Mean postoperative HKA angle achieved in knees with femoral bowing ≤5° was significantly greater when compared to knees with femoral bowing >5° (p=0.04); in knees with proximal tibia vara ≤3° was significantly greater when compared to knees with proximal tibia vara >3° (p=0.0001) and when compared to knees with proximal tibia vara >6° (p=0.0001).

Conclusion Extra-articular deformities are frequently seen in patients undergoing mobile-bearing medial UKAs, especially in knees with varus deformity>10°. Presence of an EAD significantly affects postoperative mechanical limb alignment achieved when compared to limbs without EAD and may increase the risk of limbs being placed in varus>3° postoperatively.

Clinical Relevance Since the presence of an EAD, especially in knees with varus deformity>10°, may increase the risk of limbs being placed in varus>3° postoperatively and may affect long-term clinical and implant survival outcomes, UKR in such knees should be performed with caution.

Keywords: osteoarthritis, unicompartmental knee replacement, alignment, extra-articular deformity, knee

#6209

Early Survivorship of Robotic-Assisted Unicompartmental Knee Arthroplasty

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Background:

Unicompartmental Knee Arthroplasty (UKA) is a treatment option for patients with knee osteoarthritis isolated to a single compartment. In comparison to Total Knee Arthroplasty, UKA preserves bone and ligaments and can result in shorter hospitalization and improved patient satisfaction.[i] The Australian Orthopaedic Association National Joint Replacement Registry 2015 Annual Report[ii] reports the survival rate of UKA at 2-years is 95.7%. Technological advances, including computer navigation and robotic-assisted surgery, have been introduced to improve the accuracy of bone preparation, implant positioning, and soft tissue balance in UKA. It is estimated that 15-20% of UKA surgeries in the US are performed with robotic-assistance[iii]. One such device is the NAVIO Robotic-assisted Surgical System, a semi-autonomous image-free system. There is limited data available on how robotics may affect the survivorship of UKA. This study is the first to look at the revision rate for patients undergoing UKA with the NAVIO Robotic-assisted Surgical System and determine if it is non-inferior to that referenced in the literature.

Methods:

This retrospective study included 128 patients at five sites within the US, representing surgeon adopters' initial cases. All patients underwent UKA utilizing the NAVIO Robotic-assisted Surgical System. The NAVIO system was used to plan the positioning of the implants and to prepare the bone surfaces prior to implantation. Patients were followed for a mean of 2.3 years to determine if the UKA had been revised for any reason.

Results:

Overall survivorship of the knee implant at 2 years (96 weeks) was 99.2% (95% CI: 94.6 to 99.9%). This demonstrated the knee implant's survivorship non-inferiority to that reported in the Australian Registry review of conventional UKA (95% CI: 94.6 to 99.9%). The only revision encountered during this study was due to hamstring irritation and ischial tuberosity bursitis. This revision occurred in a male less than 60 years old and a BMI < 30 kg/m^2 at 218 days post-op. There was a total of 4 (3.1%) patients who reported adverse events that were possibly or definitely related to the NAVIO System which was much less than the 16 (12.5%) subjects who reported adverse events that were possibly or definitely related to the knee implant.

Conclusion:

Early survivorship using the NAVIO System for UKA is non-inferior to standard UKA.

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#5715

Stepwise Evaluation and Surgical Correction of Instability in Total Hip Arthroplasty

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Introduction: Surgical correction of instability after total hip arthroplasty (THA) remains a complex challenge to the hip arthroplasty surgeon. At our institution, we have developed a stepwise evaluation and surgical correction strategy for patients presenting with THA instability.

Methods: 37 patients presenting to a single surgeon for evaluation of THA instability underwent a standardized pre-operative protocol to determine causative factors leading to instability. Radiographic images were reviewed for leg length, offset, cup inclination and anteversion, and dynamic changes in pelvic tilt from supine to standing, and standing to sitting. Findings were confirmed intraoperatively, and instability was addressed surgically through the stepwise algorithm.

Results: 37 consecutive patients have been prospectively revised for THA instability. Average pre-operative acetabular abduction was 47.8 degrees and anteversion was 13.4 degrees. Average pelvic incidence was 38 degrees.

The acetabular component alone was revised in 22 patients, and the stem alone in 2 patients. Both acetabaular and femoral components were revised in 4 patients. There were 9 cases where the head and liner were exchanged to a larger size. No isolated head or isolated liner exchanges were performed. Dual mobility heads were used in 20 patients (54%), with 40mm heads used in 11 patients and 36mm heads used in 6 patients. Post-operative acetabular abduction was 39.2 degrees (range 37-43) and post-operative anteversion was 27.3 degrees (range 22-34), $p<0.003$ for both.

Conclusion: Using this stepwise evaluation as a tool to guide surgical correction of instability, our study demonstrates a significant and promising decrease in the risk of recurrent instability in this high-risk population.

#5675

Lumbo-Pelvic Complex Degeneration Influences the Risk of THA Instability: A Case-Control Study

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Background: The risk of prosthetic hip dislocation is influenced by the functional acetabular cup orientation depending on the individual lumbo-pelvic complex (LPC) kinematics. Spine degeneration alters this kinematics because the LPC becomes stiffer, and the lumbar lordosis progressively reduces with a pelvis excessively posteriorly tilted in standing position. Our study aims at answering the following questions (Q): Q1) Is spine degeneration a risk factor for total hip arthroplasty (THA) instability? and Q2) Does dual mobility implant reduces the risk of instability in a group of THA elderly spine degenerated patients.

Methods: Monocentric retrospective case-control study. Between 2009 and 2017, 1672 and 1056 patients were implanted in our institution with a conventional THA and a dual mobility THA, respectively. Ninety (5.4%) and 12 (1.1%) patients dislocated their conventioanl and dual mobility prosthetic hip, respectively. One hundred and sixteen patients were allocated into three matched groups: 33 patients with unstable conventional THA (group 1-case), 41 patients with stable conventional THA (group 2-control), and 42 patients with stable dual mobility THA (group 3-control). The spino-pelvic parameters were measured from standing EOS^{TM} bi-planar images and then categorised according to them.

Results: Q1:We found the spino-pelvic parameters to be significantly different between groups 1 and 2 (table 1) suggesting spine degeneration to be more frequent and severe in group 1 compared to group 2. The pelvic incidence and the pelvic version were higher in group 1 compared to group 2 (58° ± 13° versus 51° ± 11°, 18° ± 12° versus 13° ± 9°, respectively, $p<0.01$); we found a larger PI-LL mismatch in group 1 compared to group 2 (17° ± 15° vs 8° ± 12°, respectively, $p=0.005$). Q2: We found the spino-pelvic parameters to be similar between groups 1 and 3 (table 1).

Discussion/conclusion: Our study suggests that spine degeneration increases the risk of THA instability, which might be significantly reduced by the use of a dual mobility implant. New kinematic alignment techniques for hip replacement, taking into account the individual LPC kinematics and spine-hip relation to optimize the choice for cup design and orientation, might be of interest for patients with spine degeneration in order to reduce risk of intability.

Level of evidence: Level III (Case-control study)

Table 1: Spino-pelvic parameters for each group and their comparison.

	Group	Group	Group	p-value	p-value

	1	2	3	(G1 vs G2)	(G1 vs G3)
Pelvic parameters					
Pelvic Incidence (°)	58 ± 13	51 ± 11	56 ± 12	**0.01**	0.49
Sacral Slope (°)	40 ± 8	37 ± 8	37 ± 7	0.29	0.2
Pelvic Version (°)	18 ± 12	13 ± 9	19 ± 9	**0.03**	0.95
Pelvic Tilt (°)	2 ± 8	7 ± 6	3 ± 6	**0.002**	0.36
Spinal parameters					
Lumbar lordosis (°)	41 ± 11	43° ± 12	41 ± 14	0.47	0.93
SVA (mm)	68 ± 64	36 ± 46	70 ± 52	**0.02**	0.87
SSA (°)	122 ± 11	126 ± 12	121 ± 10	0.16	0.61
PI-LL (°)	17± 15	8 ± 12	15 ± 14	**0.005**	0.61

#5752

Long-Term Results of Anatomical Custom-Made Femoral Component in Total Hip Arthroplasty

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Purpose To elucidate the long-term implant survival of cementless anatomical femoral components and longitudinal changes of stress shielding, we investigated clinical and radiological results of two different anatomical custom-made stems in total hip arthroplasty (THA) for secondary osteoarthritis due to developmental dysplasia of the hip (DDH).

Methods: 89 hips of 69 patients underwent THA using the custom-1 stem, with a stem length of 120 mm and with surface finish sand-blasted between 1994 and 1997, and 142 hips of 106 patients underwent THA using the cusom-2 stem, with a stem length of 100 mm and with the proximal half plasma-spray coated between 1997 and 2002 were investigated (Fig.1). Both custom-made stems were designed based on computer tomographic data of the femur (Fig.2) and were made of Ti-6Al-4V alloy by cutting method. The Crowe classification (group 1/2/3) was 46%/43%/11% in the custom-1 group and 53%/35%/12% in the custom-2 group. The follow-up period was 22 years (range, 21-24 years) in the custom-1 group and 18 years (range, 16-20 years) in the custom-2 group. Implant survival rate and longitudinal evaluation of stress shielding (Fig.3) were investigated.

Results: Kaplan-Meier survival analysis with aseptic loosening as the end point showed a 95.5% (95%CI: 91-99) probability of retaining the femoral component at 20 years in the custom-1 group and a 100% probability at 15 years in the custom-2 group. Kaplan-Meier survival analysis with stem revision as the end point showed a 95.5% (95%CI: 91-99) probability of retaining the femoral component at 20 years in the custom-1 group and a 95% (95%CI: 85-99) probability of retaining the femoral component at 15 years in the custom-2 group. Three stems (3.3%) were revised because of aseptic loosening and one stem (1.1%) was revised because of infection in the custom-1 group, while one well-fixed stem (0.7%) was revised due to multiple dislocation in the custom-2 group. Periprosthetic femoral fracture occurred in one custom-1 hip at 17 years (1%) and in three custom-2 hips at 13, 14, and 16 years (2%). Stress shielding progressed gradually and was seen in all hips at the latest follow-up. At 15 years postoperatively, second, third, and fourth degree stress shielding was seen in 36%, 45%, and 19% of hips in the custom-1 group and in 33%, 64%, and 3% of hips in the custom-2 group, respectively ($p<0.05$). At 20 years postoperatively, second, third, and fourth degree stress shielding was seen in 4%, 45%, and 51% of hips in the custom-1 group, respectively. Anteroposterior distal canal fill ($p=0.04$) and cortical index ($p=0.001$) predicted fourth degree stress shielding at 21- 24 years in the custom-1 group.

Discussion and Conclusions: Cementless anatomical custom-made femoral components had a survival of 95%-100% at 16-24 years postoperatively. Stress shielding progressed gradually, and periprosthetic fractures occurred in 1-2% at 16-24 years postoperatively. The stress shielding grade was significantly different for the two types of custom-made stem at 15 years because of different stem length and surface finish.

Figures

Figure 1

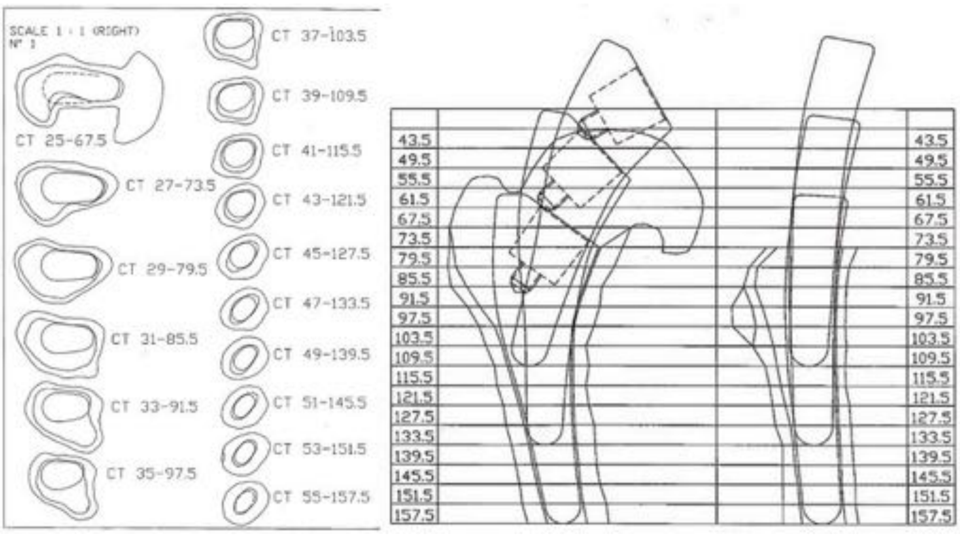

Figure 2

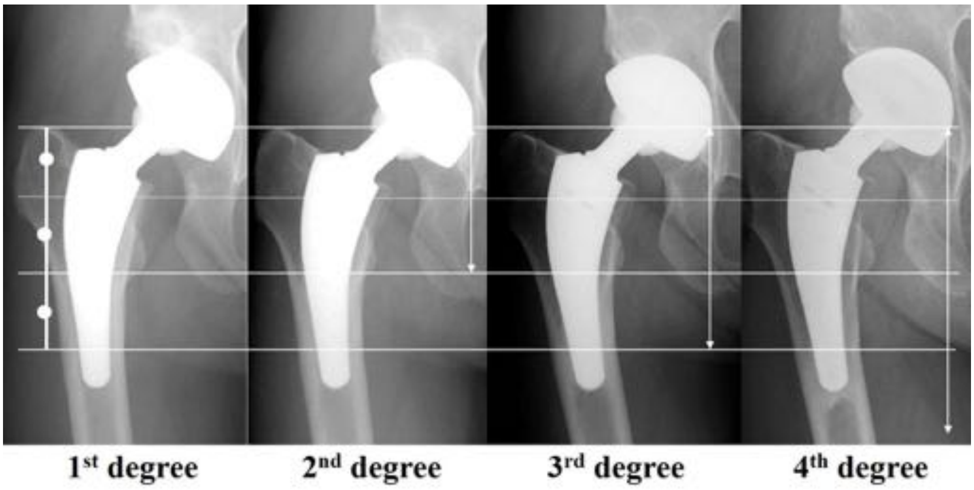

Figure 3

#6000

Longevity and Socket Wear Was Improved by Cross-Linked Polyethylene in Cemented Total Hip Arthroplasty: Minimum 10 Years Followup Study

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Background It is generally recognized that crosslinked polyethylene (XLP) reduced dramatically its wear as compared with conventional polyethylene (CON) in total hip arthroplasty (THA). However, it is unclear whether reduction of wear influence on longevity of cemented THA. **Questions/purposes** It is unknown whether XLP improve long term results of THA. We evaluated the clinical results of THA used XLP comparing it with THA used CON with respect to assessment in radiographic wear rate and overall hip survival after this improvement. **Patients and Methods** The patients were divided into the following two groups: 1) seventy-five patients (82 hips) with conventional polyethylene (CON) (group-1); 2) one hundred and twenty-seven patients (147 hips) with highly cross-linked polyethylene (XPL) (group-2) (Table 1). Diagnoses of the hip joint disease were shown in Table 2. The set of radiograph was taken at three weeks postoperatively and at the time of semiannual follow-up. The average ceramic femoral head penetration was measured with radiographs taken in the standing or supine position at the final follow-up and compared with those of three weeks postoperatively. A single researcher with use of a computerized measurement system performed all measurements on the radiographs of the two-dimensional position of the head. The average follow-up periods were 16.5 ± 4.6 (range, 10.5–23.4) years postoperatively in group-1 and 12.6 ± 2.4 (range, 10.0–17.3) years postoperatively in group-2. **Survival analysis was performed by using Kaplan-Meier plots with radiological loosening as the end point.** A follow-up was performed at minimum of 10 years after surgery. **Results** Linear penetration rates in group-1 were 0.172 ± 0.069 mm/year in supine position and 0.178 ± 0.069 mm/year in standing position ($p < 0.05$, paired t-test; $r^2 = 0.88$), and the rates in group-2 were 0.029 ± 0.024 mm/year and 0.035 ± 0.027 mm/year with significant difference ($p < 0.0005$, paired t-test; $r^2 = 0.16$). Kaplan-Meier survivorship analysis predicted a 20-year survival rate of 64.4 ± 11.2% (95% confidence interval, 42.5% to 86.4% in log rank test) for group-1 and of 99.3 ± 0.7% (95% confidence interval, 98.0% to 100% in log rank test) for group-2 ($p < 0.05$) (Fig.1). There were 16 cases in CON and one case in XLP as loosening found in the hip prostheses (Fig.1). **Conclusion** XLP improved longevity of cemented THA as compared with CON at minimum of 10 years follow-up study.

Figures

Table 1 Patient demographics (All cemented THA)

Variable	CON THA	XLP THA
Number of patients/hips	75/82	127/147
Female:male	72:3 (patients)	124:3 (patients)
Age at time of surgery (years)*	60.6 ± 10.1 (26-83)	65.8 ± 9.3 (34-81)
Follow up (years)*	16.5 ± 4.6 (10.5-23.4)	12.6 ± 2.4 (10.0-17.3)

* Values are expressed as mean ± SD, with range in parentheses.

Figure 1

Table 2 Diagnoses of the hip joint disease or causes for THA

	CON-THA		XLP-THA	
	THAs	%	THAs	%
Dysplastic	60	73.2	117	79.4
Dislocated	0	0	6	4.1
Primary	10	12.2	15	10.2
RDC	3	3.7	2	1.4
AVN	3	3.7	1	0.7
RA	2	2.4	2	1.4
Traumatic	2	2.4	1	0.7
Revision	2	2.4	2	1.4
Ankylosis	0	0	1	0.7
Total	82	100	147	100

Dysplastic/Dislocated/Primary/Traumatic: Osteoarthritis of the hip joint. RA: Rheumatoid Arthritis. RDC: Rapidly Destructive Coxarthrosis. AVN: Avascular Necrosis of the Femoral Head

Figure 2

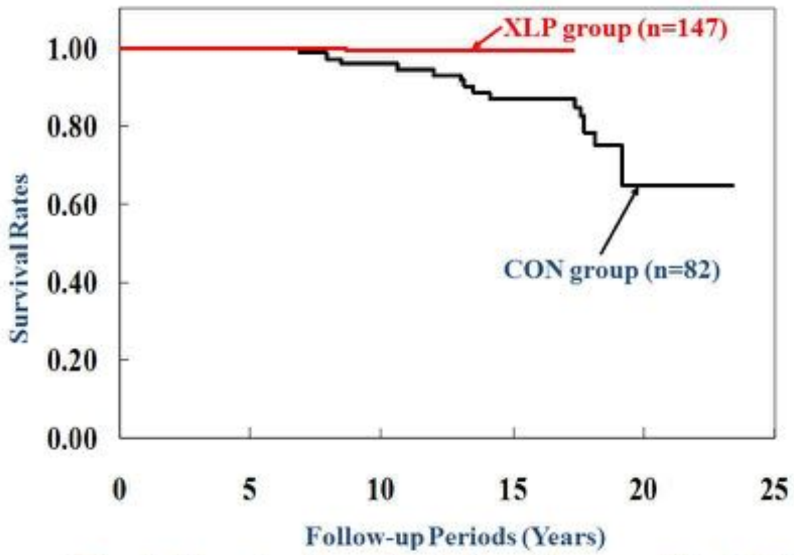

Fig. 1 Survival analysis for all cases (End Point: Radiological Loosening, Kaplan-Meier plots)

Significant Difference (p = 0.0124 in Log Rank test),
Radiological Loosening (n=16 in CON, n=1 in XLP)

Figure 3

Clinical Results of Total Hip Arthroplasty Using Modulus Stem for High Hip Dislocation

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(Introduction)

The anatomic abnormalities are observed in developmental dysplasia of the hip (DDH) and it is challenging to perform the total hip arthroplasty (THA) for some DDH patients. If acetabular cup was placed at the original acetabular position in patients with high hip dislocation, it may be difficult to perform reduction of hip prosthesis because of soft tissue contracture. The procedures resolving this problem were to use femoral shortening osteotomy, or to place the acetabular cup at a higher cup position than the original hip center. Femoral shortening osteotomy has some concerns about its complicated procedure, time consuming, and risk of non-union. Conversely, implantation of the acetabular cup at the higher cup position may eliminate these shortcomings and this procedure is considered to be preferred if possible. However, the criteria of cases without femoral shortening osteotomy are not clear. In this study, we retrospectively analysed the clinical outcomes of patients performed THAs for high hip dislocation, and clarified the adaptation of THA with or without femoral shortening osteotomy.

(Methods)

We included a total of 65 hip joints from 57 patients who underwent primary THA using Modulus stem for high hip dislocation from November 2007 to December 2015 at our institution. The mean follow up period was 5.2 years (2 - 10 years). The mean age at surgery was 65.4 years (Table 1). Thirty seven hips were classified as Crowe III, and twenty eight hips as Crowe IV based on Crowe classification.

We classified patients into two groups based on the use of femoral osteotomy. Then, we compared the surgical time, blood loss, Japanese Orthopaedic Association (JOA) Score as clinical outcomes, preoperative position of the greater trochanter, the cup position, and complications between two groups. The position of the greater trochanter was measured the height of the tip of greater trochanter from the inter teardrop line. The cup center position was assessed by measuring the distance between the cup center and ipsilateral tear drop. Receiver operating characteristic (ROC) curves were plotted for deciding the cut-off value for the height of the greater trochanter. The cut-off value presented the maximum sensitivity and specificity was determined.

(Results and Discussion)

Fifty three THAs were operated without femoral shortening osteotomy, and twelve THAs were performed with femoral shortening osteotomy. The surgical time was significantly longer in the osteotomy group than the non-osteotomy group. The mean height of the tip of the greater trochanter were 53.2±11.4mm in the non-osteotomy group and 92.2±19.7 mm in the osteotomy group (Table 2). The cut-off value of the height of greater trochanter evaluated from the ROC curve analysis was 69.5mm (Fig.1). There were no significant differences in clinical score between two groups. More ratio of revisions and fractures were observed in the osteotomy group with significant differences.ã€€

(Conclusion)

There were significant differences in postoperative complications in osteotomy group compare to non-osteotomy group. In cases with a greater trochanter tip height of 69.5 mm or less, it may be considered to avoid femoral shortening osteotomy.

Figures

Table 1 Patients demographic data and complications

	Nonosteotomy group	Osteotomy group	Total	P value
Hips, *n*	53	12	65	
Male/Female, *n*	3 / 50	0 / 12	3 / 62	1
Crowe III/Crowe IV, *n*	37 / 16	0 / 12	37 / 28	<0.01*
Age (years)	64.5 ± 8.4	69.6 ± 6.5	65.4 ± 8.3	0.05
Height (cm)	150.0 ± 6.2	146.4 ± 7.8	149.3 ± 6.6	0.08
Body Weight (kg)	54.9 ± 11.5	49.8 ± 9.0	53.9 ± 11.2	0.126
BMI (kg / m^2)	24.3 ± 4.3	23.2 ± 3.5	24.1 ± 4.1	0.51
Surgical time (minitues)	127.0 ± 34.2	199.3 ± 33.6	140.4 ± 44.1	<0.01*
Blood loss (ml)	539.8 ± 298.0	627.8 ± 251.2	556.1 ± 290.2	0.168
Preoperative JOA score	47.8 ± 12.4	44.8 ± 23.0	47.3 ± 14.7	0.322
Postoperative JOA score	82.4 ± 12.4	77.7 ± 12.1	81.5 ± 12.4	0.132
Complications				
Infection	0	0	0	1
Dislocation	1	2	3	0.09
Revision	0	2	2	0.03*
Fracture	2	3	5	0.04*
Nerve palsy	0	0	0	1
Non-union	-	1	1	-
Total	3	6	9	<0.01*

*Statistically significant difference
P values were calculated with Fisher's exact test or Mann-Whitney U-test
JOA: Japanese Orthopaedic Association

Figure 1

Table 2 Comparison of radiographic data between non-osteotomy group and osteotomy group

		Non-osteotomy group	Osteotomy group	Total	P value
The cup center position	horizontal (mm)	28.8 ± 4.0	25.3 ± 2.1	28.1 ± 3.9	<0.01*
	vertical (mm)	34.8 ± 7.1	21.0 ± 8.2	32.3 ± 9.0	<0.01*
The preoperative position of the Greater trochanter (mm)		53.2 ± 11.4	92.2 ± 19.7	60.4 ± 20.1	<0.01*

*Statistically significant difference
P values were calculated with Mann-Whitney U-test

Figure 2

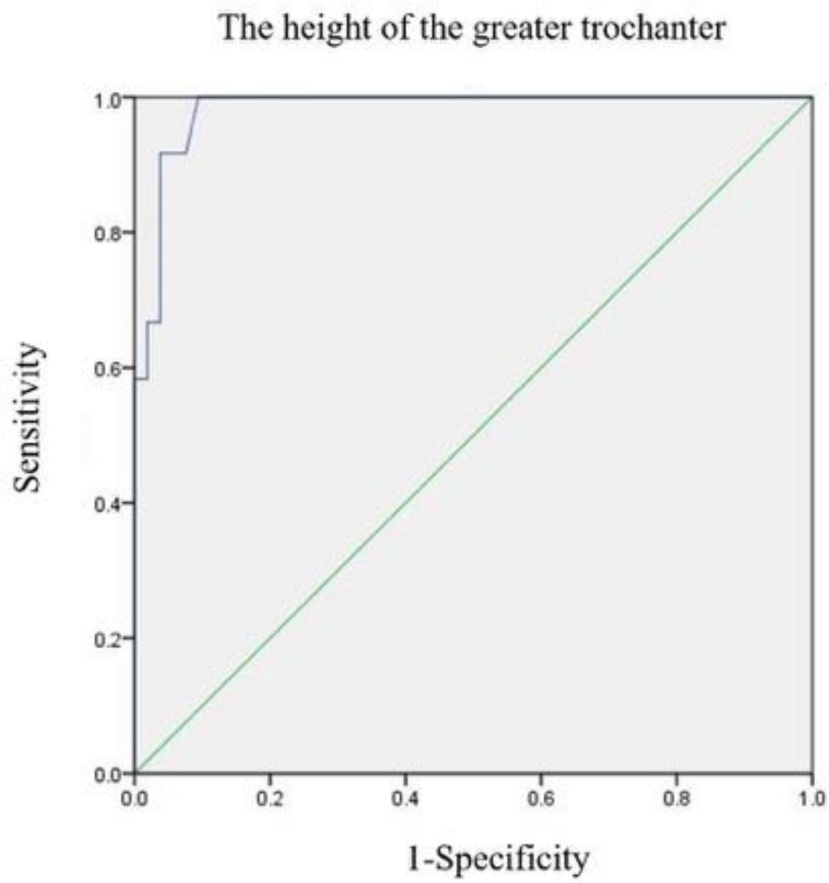

Fig.1 Receiver operating characteristic (ROC) curve analysis of the height of the greater trochanter

Figure 3

#5803

Survivorship of Porous Titanium Acetabular Components With an Average of 5-Year Follow-Up

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Introduction:

Highly porous arthroplasty components have becoming increasingly popular over the past several years, as increased porosity is designed to maximize bony ingrowth. One such example is a highly porous titanium acetabular component for total hip arthroplasties (THA). However, past studies have demonstrated up to 30.3% of progressive radiolucency around this component 3-years after implantation. The purpose of this study was to report the mid-term results of this porous titanium acetabular component.

Methods:

IRB approved retrospective review of prospectively collected data on a consecutive single-surgeon series of all patients undergoing THA with a highly porous titanium acetabular component from 8/2011 – 12/2014 with a minimum of 3-year follow-up. Radiographs were taken immediately post-operatively, and at most recent follow-up. The radiographs were reviewed by 2 separate senior orthopedic surgeons and evaluated for progressive radiolucencies in DeLee zones. Patients whom both observes noted progressive radiolucency were deemed to have progressing radiolucency. Primary endpoint was revision of acetabular component due to progressive lucency and/or failure. Revisions due to infection, for traumatic reasons (i.e. fracture), or only the femoral component were excluded.

Results:

A total of 221 patients met inclusion criteria with and average of 61.9-month follow-up (range 40.1-80.1 months). There were 14 (6.33%) patients whom both observers agreed had progressing radiolucency. There was a total of 13 revision THAs: 4 due to infection and 9 due to periprosthetic fracture. There were no patients (0%) who had a revision of the acetabular component due to failure/progressive radiolucency.

Conclusion:

Despite a recent report demonstrating high rates or progressive radiolucency, in the largest study of porous titanium acetabular components, we found a 100% survivorship with a low rate of progressive radiolucency at an average of 61.9-months post-operative.

#5938

Opioid Abuse Is an Independent Risk Factor for Deep Vein Thrombosis, Pulmonary Embolism, Venous Thromboembolism Following Primary Total Joint Arthroplasty: A Matched-Control Analysis

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BACKGROUND: Opioids are known to negatively impact coagulation, cognition, and immunity, which combined can impact postoperative outcomes following either total knee arthroplasty (TKA) and total hip arthroplasty (THA). The purpose of this study was to compare the odds and incidence of deep vein thrombosis (DVT), pulmonary embolism (PE), venous thromboembolism (VTE), amongst opioid-abusers (OAS) and non-abusers (NAS) undergoing primary total joint arthroplasty (TJA).

MATERIALS AND METHODS: A retrospective review was performed using the Medicare Standard Analytical Files of the PearlDiver supercomputer (PearlDiver Technologies, Fort Wayne, IN). Patients who underwent TKA or THA were queried using International Classification of Disease, ninth revision (ICD-9) codes 81.54 and 81.51, respectively. Patients with a history of opioid abuse or dependency undergoing either primary TKA or THA served as our study group, whereas those patients without a diagnosis served as our control group. Patients in both groups were matched to control groups according to age, gender, and Charlson-Comorbidity Index (CCI). Four cohorts were formed and were followed for 90-days and rates of DVT, PE, VTE, and use of lower extremity doppler were assessed and compared. Statistical analysis was performed using the programming language R.

RESULTS: After the random matching process there were 22,628 patients (female = 15,182; male = 7,240; unknown = 206) who underwent primary TKA with (n = 11,314) and without (n = 11,314) a diagnosis of opioid abuse/dependency. There were 14,042 patients (female = 7,918; male = 6,000; unknown = 124) undergoing primary THA with (n = 7,021) and without (n = 7021) concomitant diagnosis of opioid abuse/dependency. OAS undergoing TKA had greater odds and incidence of developing DVT (OR: 1.53, 95%CI: 1.23 – 1.91, p<0.001), PE (OR: 1.25, 95%CI: 0.86 – 1.80, p = 0.229, and VTE (OR: 1.43, 95%CI: 1.17 – 1.76,p<0.001) within 90 days following a primary TKA compared to patients without a history of opioid abuse or dependency. Similarly, patients undergoing primary THA with a diagnosis of opioid abuse had greater odds of developing DVT (OR: 1.31, 95%CI: 0.99 – 1.74, p = 0.058), PE (OR: 1.34, 95%CI: 0.81 – 2.24, p = 0.249), and VTE (OR: 1.45, 95%CI: 1.11 – 1.88, p=0.005) within 90 days following primary THA, compared to patients without a history of opioid abuse or dependency. With the increased incidence of thromboembolic complications, the odds of using lower extremity doppler in OAS undergoing primary TKA was found to be greater (OR: 1.86, 95%CI: 1.09 – 3.16, p = 0.022) compared to patients in the control group. Alternatively, opioid abusers undergoing primary THA were less likely (OR: 0.88, 95%CI: 0.45 – 1.74, p = 0.731) to have a lower extremity doppler exam performed on them compared to the control group.

CONCLUSION: Opioid abusers who undergoing TJA show an increased risk of complications compared to NAS. Appropriate recognition, pre-surgical optimization, and patient education especially in opioid abusers undergoing TJA is essential to mitigate these complications and improve patient outcomes.

Figures

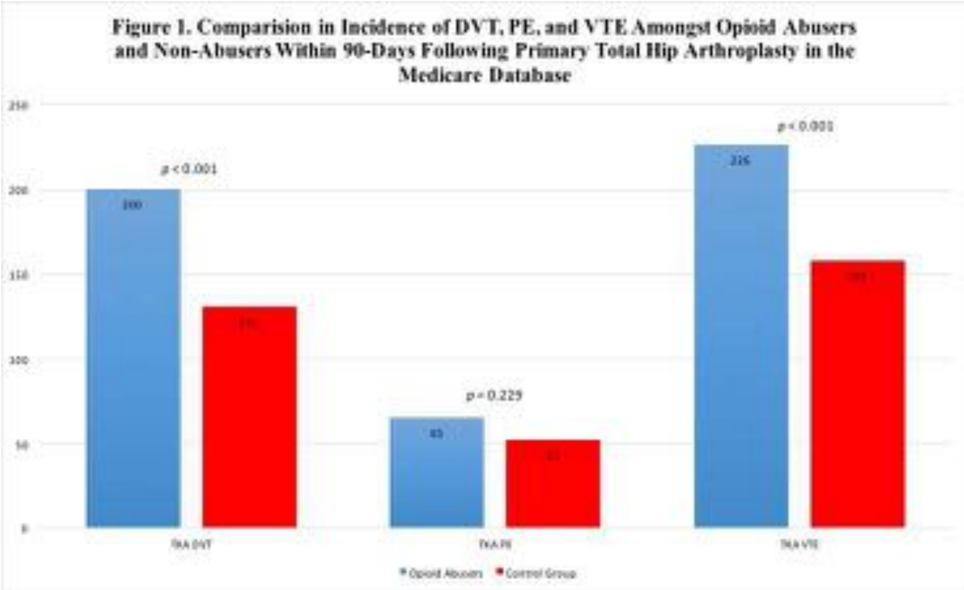

Figure 1

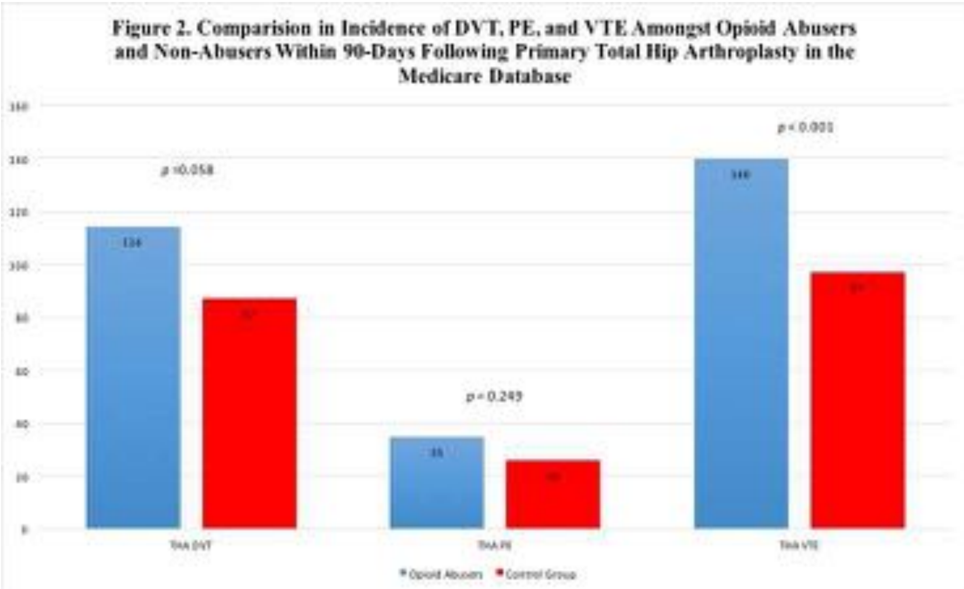

Figure 2

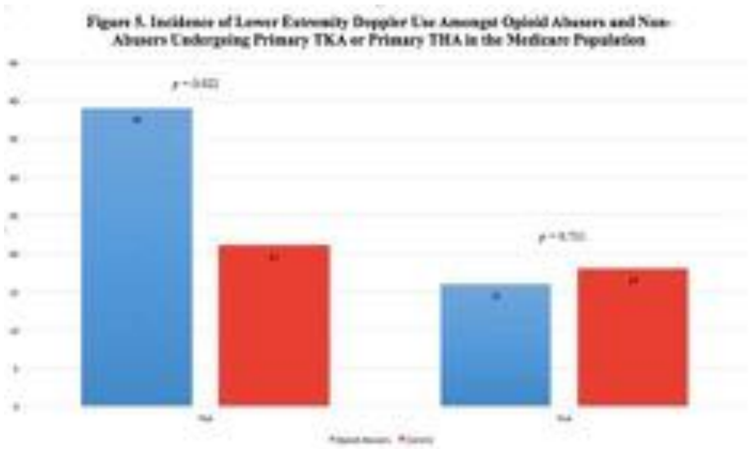
Figure 5. Incidence of Lower Extremity Doppler Use Amongst Opioid Abusers and Non-Abusers Undergoing Primary TKA or Primary THA in the Medicare Population

[Figure 3](#)

#5568

Outcome Analysis of Hip or Knee Arthroplasty in Patients With Cirrhotic Liver Disease

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Present helpful measures to prevent expected complications that occur in patients with liver cirrhosis undergoing arthroplasty 218 patients who underwent hip or knee arthroplasty were included in this study. Prognosis of patients with underlying disease of liver cirrhosis and those without are compared with measures.

Significant negative results (including medical and surgical complications and mortality) occurred at a rate of 53.6% (59 of 110) in the cirrhotic group compared with a rate of 11.8% (13 of 110) in the control group. In THA group, 8.1% (3 of 37) of cirrhotic patients whereas 2.7% (1 of 36) of controls patients had medical compolications, 13.5% (5 of 37) of cirrhotic patients whereas 5.6% (2 of 36) of controls patients had joint-related complications(P = 0.84, P = 0.43). In TKA group, 35.2% (12 of 34) of cirrhotic patients whereas 5.5% (2 of 36) of controls patients had medical complications, 17.6% (6 of 34) of cirrhotic patients whereas 2.8% (1 of 36) of controls patients had joint-related complications(P = 0.03, P = 0.05). In urgent group, 43.6% (17 of 39) of cirrhotic patients whereas 10.5% (4 of 38) of controls patients had medical compolications. 15.3% (6 of 39) of cirrhotic patients whereas 7.8% (3 of 38) of controls patients had joint-related complications(P = 0.01, P = 0.21).

The risk of arthroplasty on patients with liver cirrhosis is higher than normal patients. Surgeons should carefully assess all cirrhotic patients pre- and postoperatively.

#5605

Patient Satisfaction and Clinical Outcomes Are Better With a Medial-Stabilized Implant vs. a Posterior-Stabilized Implant

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Introduction

There is current debate concerning the most biomechanically advantageous knee implant systems, and there is also currently great interest in improving patient satisfaction after knee arthroplasty. Additionally, there is no consensus whether a posterior-stabilized (PS) total knee device is superior to a more congruent, cruciate-substituting, medially-stabilized device (MS). This study compared the clinical outcomes of two such devices. The primary hypothesis was that the clinical outcomes and specifically the patient satisfaction as measured by the Forgotten Joint Score would be better in the MS group.

Methods

This prospective, randomized, blinded Level 1 study compared the outcomes of 100 patients who received a Medacta PS device and 101 patients who received a Medacta Sphere device (Medacta Intl., Lugano, Switzerland). All patients undergoing elective primary total knee arthroplasty were eligible for participation. Institutional Review Board approval and informed consent from participants were obtained. The devices were implanted using an anatomic alignment/calipered-measured resection surgical approach. Clinical and radiographic assessments were performed preoperatively, 6 weeks, 6 months, and annually. Data were compared using T-test with a significance level of 0.05.

Results

The minimum follow-up period is 2 years. There were no statistically significant differences in demographic characteristics and preoperative scores; tourniquet time was 7.24% longer for the PS group (40.28 min vs 37.56 min, $P < .0086$). There were significant differences between groups for the 1 year and 2 years postop Knee Society scores, Forgotten Joint Score, and ROM; in every case where there was a statistically significant difference, the results were better in the Sphere group. Alignment was not different between the groups (preoperative or postoperative). For example, the FJS was 65.72 in the Sphere group at 2 years, 54.33 in the PS group ($p=0.02$). The maximum active flexion at 2 years was 129.75 in the Sphere group, in the PS group it was 122.27 ($p=0.03$)

Conclusion

The clinical outcomes of the Sphere group at 1 and 2 years, including the Forgotten Joint Score and flexion, were better statistically, and there was a statistically longer tourniquet time for the PS group. At the minimum 2-year follow-up, the results demonstrate superiority of the medially-stabilized device in terms of multiple clinical outcomes, including patient satisfaction as measured by the Forgotten Joint Score. These findings support the use of a medially-stabilized knee implant system, and support the conclusion that this design, in conjunction with an anatomic alignment, calipered-measured resection surgical technique, offers improved biomechanics and kinematics.

#5818

The Effect of Local Anesthetic Infiltration Between the Popliteal Artery and Capsule of Knee (IPACK) on Pain After Total Knee Arthroplasty: A Double Blinded Prospective Randomized Trial

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Introduction:

Regional anesthesia is commonly utilized to minimize postoperative pain, improve function, and allow earlier rehabilitation following Total Knee Arthroplasty (TKA). The adductor canal block (ACB) provides effective analgesia of the anterior knee. However, patients will often experience posterior pain not covered by the ACB requiring supplemental opioid medications. A technique involving infiltration of local anesthetic between the popliteal artery and capsule of knee (IPACK) targets the terminal branches of the sciatic nerve, providing an alternative for controlling posterior knee pain following TKA.

Materials and Methods

IRB approval was obtained, a power analysis was performed, and all patients gave informed consent. Eligible patients were those scheduled for an elective unilateral, primary TKA, who were ≥ 18 years old, English speaking, American Society of Anesthesiologists physical status (ASA PS) classification I-III. Exclusion criteria included contraindication to regional anesthesia or peripheral nerve blocks, allergy to local anesthetics, allergy to nonsteroidal anti-inflammatory drugs (NSAIDs), chronic renal insufficiency with GFR < 60, chronic pain not related to the operative joint, chronic (> 3 month) opioid use, pre-existing peripheral neuropathy involving the operative limb, and body mass index (BMI) ≥ 40 kg/m^2.

Patients were randomized into one of two treatment arms: Continuous ACB with IPACK (IPACK Group) block or Continuous ACB with sham subcutaneous saline injection (No IPACK Group). IPACK Group received single injection of 20 mL 0.25% Ropivacaine. Postoperatively, all patients received a standardized multimodal analgesic regimen. The study followed a double-blinded format. Only the anesthesiologist performing the block was aware of randomization status. Following surgery, a blinded medical assessor recorded cumulative opioid consumption, average and worst pain scores, and gait distance.

Results

72 people were enrolled in the study and three withdrew. There were 35 people in the IPACK group and 34 in the NO IPACK group. There was no difference demographically between the groups. In the Post Anesthesia Care Unit (PACU), the average (P=0.0122) and worst (P=0.0168) pain scores at rest were statistically lower in the IPACK group. There was no difference in the pain scores during physical therapy. (P=0.2080) There was no difference in opioid consumption in the PACU (P=0.7928), at 8 hours (P=0.2867), 16 hours (P=0.2387), 24 hours (P=0.7456), or 30 hours (P=0.8029). There was no difference in pain scores on POD 1 in the AM (P=0.4597) or PM (P=0.6273), nor was there any difference in walking distance (P=0.5197). There was also no difference in length of stay in the PACU (P=0.9426) or hospital (P=0.2141)

between the two groups.

Discussion/Conclusion

Overall, pain was well controlled between the two groups. The IPACK group had lower pain scores at rest in the PACU, but this may not be clinically significant. The routine use of the IPACK is not supported by the results of this study. There may be use of the IPACK block as a rescue block or in patients whom have contraindications to our standard multimodal treatment regimen, or in patients with chronic pain or opioid dependence.

#5965

Does the Amount of Opioid Consumed Influence How Patients Rate Their Experience of Care After Total Knee Arthroplasty?

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Background:

With legislative efforts aimed at optimizing value of care, surgeons performing total knee arthroplasty (TKA) are faced with increased responsibility of optimizing patient perception of care. However, pain following TKA may negatively influence patient perception of care, as measured by Press Ganey (PG) patient satisfaction surveys. While opioid-based medications are best suited for acute pain alleviation, awareness of a growing opioid epidemic has spurred efforts to reduce its administration. Therefore, this study assessed the correlation between post-operative opioid consumption and 7 PG question domains: 1) Overall hospital rating; 2) Communication with nurses; 3) Response time of hospital staff; 4) Communication with doctors; 5) Hospital environment; 6) Pain Management and; 7) Communication about medication.

Methods:

We reviewed our institutional PG database for patients that received a TKA between 2011 to 2014. A total of 406 patients were analyzed (mean age= 66, 73.4% female) **(Table 1, 2)**. Opioid consumption was measured using a morphine milli-equivalent conversion algorithm. A descriptive analysis was performed to examine patient demographics. Bivariate correlation analysis was conducted to assess the association between opioid consumption and Press-Ganey survey domains**.** Spearman's *r* was utilized to assess the strength of the association.

Results: No association between total opioid consumption and Overall hospital rating (r=0.044) **(Table 3)**, Communication with doctors (r=0.080), Communication with nurses (r=0.072), Responsiveness of hospital staff (r=0.084), Pain management (r=0.100), Communication about medicines (r=0.083), or Hospital environment (r=0.155) were found.

Discussion: Our findings demonstrate that PG scores are not influenced by immediate post-operative opioid use. These results suggest opioid-based pain medications should be administered exclusively on the basis of clinical guidelines and patient needs without concern regarding satisfactions scores and reimbursement penalties.

Figures

Table 1. Descriptive analysis demonstrating patient demographics

	Mean	Standard Deviation
Age in years	66	9.5
BMI (kg/m^2)	32.4	7.2
Length of Stay	2.8	1.3
VAS Score	4.4	2.1
Morphine milliequivalents (mEq)	82.14 (range; 0 to 779.2)	
Communication with doctors	3.9	0.3
Communication with nurses	3.7	0.4
Responsiveness of hospital staff	3.6	0.7
Pain management	3.7	0.5
Communication about medicines	3. 4	0.8
Hospital environment	3.6	0.6
Hospital Rating	8.9	1.3

Figure 1

Table 2. Descriptive analysis demonstrating patient demographics

	Percentage
Female	73.4%
Race	
White	47.8%
Black	48.8%
Asian	0.5%
American Indian	0.7%
Other	2.2%
ASA score*	
ASA I	1.7%
ASA II	47.3%
ASA III	45.3%
ASA IV	0.5%

* American Society of Anesthesiologists physical status classification

Figure 2

Table 3. Bivariate correlation analysis between survey elements and opioid consumption

	r	p-value
Communication with doctors	0.080	0.464
Communication with nurses	0.072	0.510
Responsiveness of hospital staff	0.084	0.521
Pain management	0.100	0.447
Communication about medicines	0.083	0.571
Hospital environment	0.155	0.237
Hospital Rating	0.044	0.710

Figure 3

#5515

Does Preoperative Diabetes Affect the Achievement of Forgotten Knee Status in TKR Patients

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Introduction : Forgotten knee is the terminology which is used to describe a post TKR patient who is completely unaware of his knee implant. Various factors like age, sex, BMI, pre operative pain, pre operative patella symptoms have been studied to see their cause effect relationship on the achievement of forgotten knee status by the patient. All the published data till to date shows no relationship between the two

Aim : To determine whether pre operative DM negatively influence the achievement of forgotten knee status post TKR

Materials and Methods: 100 patients were studied for the the forgotten knee status post TKR. All the patients were asked a direct question by the independent evaluator at one year post operatively “Whether they have forgotten the presence of knee implant in their body? “80 patients were female with a mean age of 67 years20 were male with a mean age of 71 years. Out of 80 females 32 had DM and out of 20 males 6 had DM

Results : 32 out of 48 non DM females (66.67%) achieved forgotten knee status whereas 17 out of 32 DM females (53%) achieved forgotten knee status. 11 out of 16(69%) non DM males achieved forgotten knee status whereas 4 out 6 DM males (66%) achieved a forgotten knee status.

Conclusion: Diabetic females had a statistically significant less chances of achieving a forgotten knee as compared to non diabetic females, The chances of achieving forgotten knee in almost the same in diabetic and non diabetic males

#5770

Influence of Femoral Component Sizing on Patient Satisfaction After TKA.

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Background:

Under- or oversizing of either component of a total knee implant can lead to early component loosening, instability, soft tissue irritation or overstuffing of joint gaps. All of these complications may cause postoperative persistent pain or stiffness.
While survival of primary TKA's is excellent, recent studies show that patient satisfaction is worse. Up to 20% of the patients are not satisfied with the outcome as and residual pain is still a frequent occurrence.

The goal of this study was therefore to evaluate if the sizing of the femoral component, as measured on a 3D-reconstructed projection, is related to patient reported outcome measures.

From our prospectively collected TKA outcome database, all patients with a preoperative CT and a postoperative X-ray of their operated knee were included in this study. Of these 43 patients, 26 (60,5%) were women and 17 (39,5%) were men. The mean age (+/-SD) was 74,6 +/- 9 years.

Methods:

CT scans were acquired. All patients underwent TKA surgery in a single institution by one surgical team using the same bi-cruciate substituting total knee (Journey II BCS, Smith&Nephew, Memphis, USA). Using a recently released X-ray module in Mimics (Materialise NV, Leuven, Belgium), this module allows to align the post-operative bi-planar x-rays with the 3D-reconstructed pre-operative distal femur and to determine the 3D position of the bone and implant models using the CAD-file of the implant. This new technique was validated at our department and was found to have a sub-degree, sub-millimeter accuracy. Eleven zones of interest were defined. On the medial and the lateral condyle, the extension, mid-flexion and deep flexion facet were determined. Corresponding trochlear zones were defined and two zones were defined to evaluate the mediolateral width. In order to compare different sizes, elastic deforming mesh matching algorithms were implemented to transfer the selected surfaces from one implant to another. The orthogonal distances from the implant to the nearest bone were calculated. Positive values represent a protruding (oversized) femoral component, negative values an undersized femoral component. The figure shows the marked zones on the femoral implant. The KOOS subscores and KSS Satisfaction subscore were evaluated.

Results:

Two-step cluster analysis based on the clinically relevant zones on both medial (zone 12, 14 and 17) and lateral (zone 2, 5 and 9) femoral condyle of the implant, led to the formation of two clusters. Cluster 1 contained 23 patients with, in general, an undersized femoral component (negative values) whilst cluster 2 contained 20 patients with in general an oversized femoral component (positive values). (see graph) No significant differences were found between both clusters regarding demographics.

Regarding PROM data, a significant difference was found for KOOS Symptoms (p=0.037) and a KOOS Pain (p=0.05). Other PROMs are not significantly different between both clusters.

Conclusion:

Our data shows that undersizing the femoral component results in less postoperative pain and symptoms. The clinical consequence of this study is that in case of in between femoral component sizes, the smallest size should be chosen to diminish the occurrence of postoperative pain and symptoms.

Figures

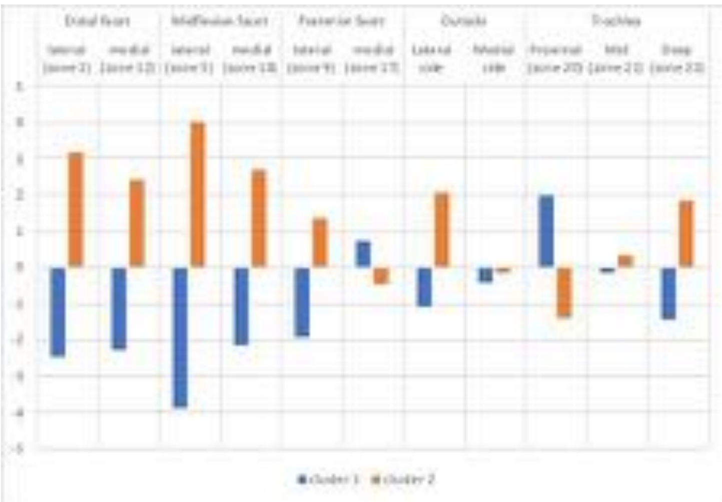

Figure 1

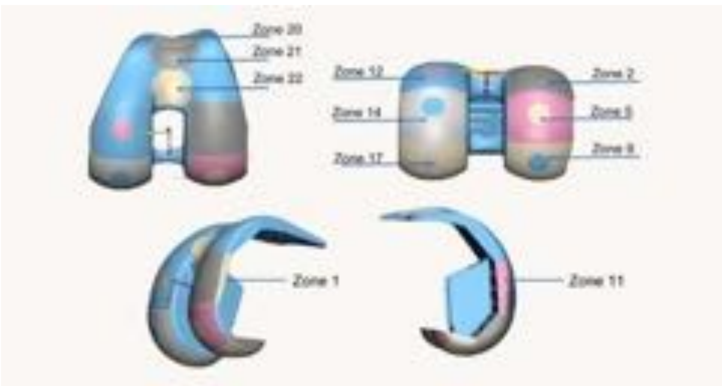

Figure 2

#6067

Early Patient Outcomes and Satisfaction of Robotic-Assisted Total Knee Arthroplasty

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Introduction: Robotic systems have been used in TKA to add precision, although few studies have evaluated clinical outcomes. We report on early clinical results evaluating patient reported outcomes (PROs) on a series of robotic-assisted TKA (RAS-TKA) patients, and compare scores to those reported in the literature.

Methods: We prospectively consented and enrolled 106 patients undergoing RAS-TKA by a single surgeon performing a measured-resection femur-first technique using a miniature bone-mounted robotic system. Patients completed a KOOS, New Knee Society Score (2011 KSS) and a Veterans RAND-12 (VR-12) pre-operatively and at 3, 6 and 12 months (M) post-operatively. At the time of publication 104, 101, and 78 patients had completed 3M, 6M, and 12M PROs, respectively. Changes in the five KOOS subscales (Pain, Symptoms, Activities of Daily Living (ADL), Sport and recreation function (Sport/Rec) and Knee-related Quality of Life (QOL)) were compared to available literature data from FORCE – TJR [1][2], a large, prospective, national cohort of TJR patients enrolled from diverse high-volume centers and community orthopaedic practices in the U.S, as well as to individual studies reporting on conventional (CON-TKA) and computer-assisted (CAS-TKA) at 3M [3], and on conventional TKA at 6M [4]. The 2011 KSS is a validated method for quantifying patient's expectations and satisfaction with their TKA procedure. Improvements in the 2011 KSS were compared with literature data at 6M post-operatively [5].

Results: RAS-TKA PRO's significantly improved at 3, 6, and 12M from pre-operative baseline values (tables 1 and 2). When compared to the FORCE registry cohort data, the improvement in KOOS subscales were generally higher for RAS for pain at 6M [1], and for pain, ADL, and QOL at 1Y when compared with FORCE 2Y data [2] (table 1). Higher improvements were also seen at 3M [3], except for Sports/Rec, and at 6M for symptoms and QOL [4] when compared with smaller cohort studies (table 1).

Improvements in 2011 KSS patient satisfaction and functional scores at 6M were 11 and 10 points greater than those reported for conventional TKA (table 2, figure 1). A mean of 31 pts for the Patient Satisfaction score indicates that on average patients were 'Satisfied' with their knee function and pain level (table 2). Mean rates of dissatisfaction with knee pain level and function were 9.2%, 3.8% and 3.1% at 3, 6, and 12M postoperatively, respectively. A mean of 10pts for the Expectation score post-operatively indicates that on average patients felt their expectations for pain relief, ADL, and leisure/sports/rec activities were between "Just Right" or "Too Low".

Discussion: Early results of RAS-TKA demonstrated significant improvements in pain, function, and QOL from baseline pre-operative values. PROs for robotic TKA also compared favorably with results reported in the literature; however, additional randomized control studies are required to provide more meaningful comparisons with conventional techniques and with other advanced technologies.

Figures

Table 1. – KOOS subscale scores for RAS-TKA and literature data (*p<0.05).

	RAS-TKA							Gøthesen 2014 [3]				Roos 2003 [4]		Li 2017 [1]		Lyman 2018 [2]	
	Pre-Op	3M	6M	1Y	Δ Pre-op & 3M	Δ Pre-op & 6M	Δ Pre-op & 1Y	Δ Pre-op & 3M		P value 3M	P value 3M	Δ Pre-op & 6M	P value 6M	Δ Pre-op & 6M	P value 6M	Δ Pre-op & 2Y	P value 1-2Y
KOOS Subscale	n=105	n=104	n=101	n=78	n=104	n=101	n=78	Conv. n= 90	CAS n= 92	ΔRAS vs ΔConv.	ΔRAS vs ΔCAS.	Conv. n=97	ΔRAS vs ΔConv.	Reg. n=2,792	ΔRAS vs ΔReg	Reg. n = 1114	ΔRAS vs ΔConv
Pain	42.6	75.3	82.8	85.2	32.6	40.5	43.4	19.7	27.4	<.001*	0.06	41	0.86	31.1	<0.001*	32.1	0.04*
Symptoms	45.2	72.4	78.0	79.4	27.1	32.8	34.5	7.0	13.1	<.001*	<.001*	25	0.01*	-	-	38.2	0.36
ADL	45.3	78.6	83.8	86.3	32.9	38.5	41.4	20.9	26.3	<.001*	0.01*	36	0.38	-	-	31.1	<.001*
SportRec	20.5	40.7	49.7	59.2	20.0	29.0	40.1	7.6	21.1	0.02*	0.84	32	0.57	-	-	33.9	0.18
QOL	21.1	62.2	67.5	72.6	40.9	46.6	52.1	27.8	35.0	0.01*	0.01*	40	0.01*	-	-	42.8	0.01*

Table 2 – 2011 Knee Society Scores (KSS) for RAS-TKA and literature data

	RAS-TKA						Uefuji 2015 (Conv-TKA) [5]			
	Pre-Op	3M	6M	1Y	Δ Pre-op & 3M	Δ Pre-op & 6M	Pre-Op	6M	Δ Pre-op & 6M	P value 6M ΔRAS vs ΔConv.
2011 KSS	n=108	n=104	n=101	n=78	n=104	n=101	n=52	n=52		
Expectation (15 pts)	14.0	10.2	10.2	10.5			12	10	-	-
Satisfaction (40 pts)	12.1	29.4	31.2	31.9	17.3	19.2	14	22	8	<.001*
Functional (100 pts)	36.7	62.2	67.3	70.6	25.3	30.5	44	64	20	<.001*
Objective	22.0	72.9	72.3	74.7	50.9	50.3	-	-	-	-

Figure 1

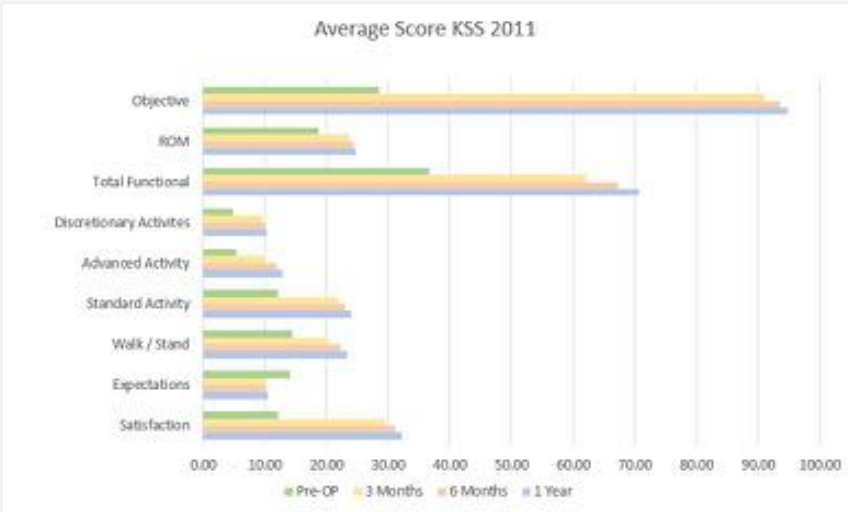

Figure 1. 2011 KSS at pre-op, and at 3, 6, and 12 months post-op for RA-TKA.

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Figure 2

#5650

Patient Perceptions of Robotically Assisted Hip and Knee Arthroplasty

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Introduction & Aims

Robotic arthroplasty surgery has proliferated in recent years. Drivers of this change include improved outcomes, accuracy, precision, and patient satisfaction. No previous studies have assessed patient attitudes to this new technology.

This study addresses patient perceptions and awareness regarding robotic arthroplasty and identifies the sources of their knowledge.

Methods

Once Institutional ethics board approval was obtained we surveyed 100 consecutive patients attending the OPD for evaluation of Hip or Knee osteoarthritis. The survey consisted of 25 questions which covered topics such as knowledge, opinion and perceptions of robotically assisted surgery and was formulated based on previously validated questionnaires examining perceptions of same day arthroplasty surgery, the Direct Anterior Approach and Hip resurfacing. The surveys were completed anonymously to exclude any potential for surgeon associated bias

Results

Sixty seven percent of respondents were female and 33% male, 10% were aged < 50, with 32% aged between 51 and 64, and the rest 58% aged over 65 years. Just 7% of patients had learned of Robotic surgery from health professionals whilst 41% learned of it from TV or Radio, 32% from family and friends and 11% from the internet. Interestingly,

65% felt they would recover faster post robotic surgery, 60% felt they would have had greater postoperative mobility and 70% thought it would take less time to perform. 48% felt they would have a reduced chance of developing an infection, 57% opined that they would lose less blood and 62% felt it more accurate and 59% expected it to result in fewer complications. Seventy three percent of participants expected the surgery to be performed by the robot whose movements were programmed by the surgeon and just 17% thought the surgery performed by the surgeon whose movements are controlled by the robot and 42% percent of people felt that robotically assisted surgery would allow surgeons to perform more complex joint replacement procedures.

Conclusion

This study highlights the mismatch between patient perceptions and reality. Patients are increasingly aware of surgical innovations due to media exposure and often seek out specific procedures. The Orthopaedic community must reliably inform and educate patients of surgical innovations, based on results from research which is both reliable and reproducible.

#5588

YouTube as a Source of Patient Information for Knee Arthroplasty and Knee Arthritis

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PURPOSE:

YouTube is a video sharing platform that is a common resource for patients seeking medical information. The objective of this study is to assess the educational quality of YouTube videos pertaining to total knee arthroplasty and knee arthritis.

METHODS:

A systematic search for the terms “knee replacement” and “knee arthritis” was performed using Youtube’s search function. Data from the 60 most relevant videos were collected for each search term. Videos not in English or those without audio or captions were excluded. Quality assessment checklists with a scale of 0 to 10 points were developed to evaluate the video content. Videos were grouped into poor quality (grade 0-3), acceptable quality (grade 4-7) and excellent quality (grade 8-10), respectively. Four independent reviewers assessed the videos using the same grading system and independently scored all videos. Discrepancies regarding the scoring were clarified by consensus discussion.

RESULTS:

Overall 106 videos were categorized. For videos regarding total knee replacements, the average number of views was 135,074 with an average duration of 14.53 minutes. Half of the videos were published by a physician or hospital sponsor and were for educational purposes. 64% of videos were of poor educational quality (32/50), 28% were of acceptable quality (14/50), and 8% were of good educational quality (4/50). Common missing information included discussion of surgical complications and implant duration. For videos regarding knee arthritis, the average number of views was 243,346 with an average duration of 4.97 minutes. 39% were published by a physician or hospital sponsor, with 64% of videos made for educational purposes. 66% of videos were of poor educational quality (37/56), 32% were of acceptable quality (18/56), and 2% were of good educational quality. The most common missing information were causes and risk factors for knee arthritis and long-term prognosis.

CONCLUSIONS:

The present study suggests that YouTube is a poor educational source for patients regarding knee arthroplasty and knee arthritis. Recognizing the limitations of YouTube as well as which topics are not commonly presented may guide clinicians to better educate their patients.

Figures

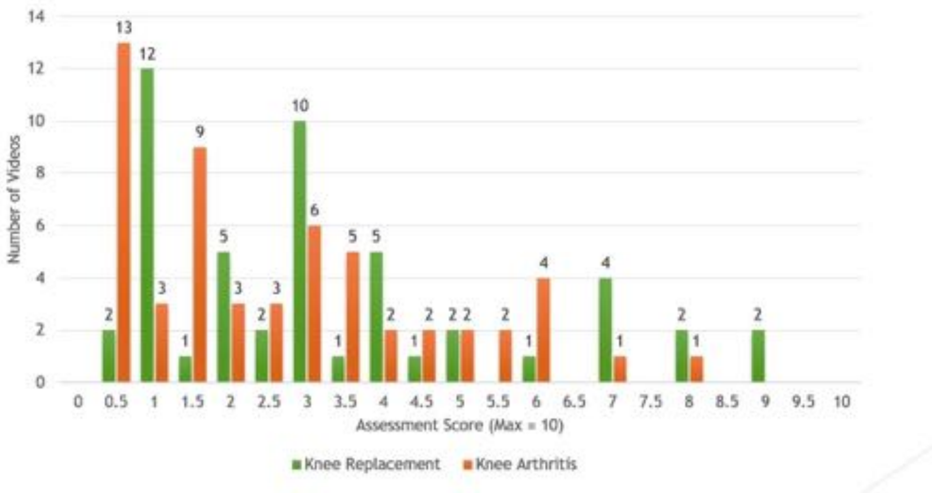

Figure 1

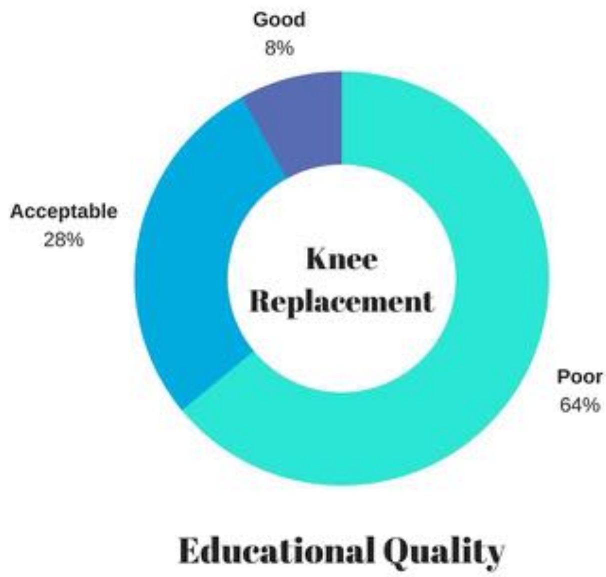

Figure 2

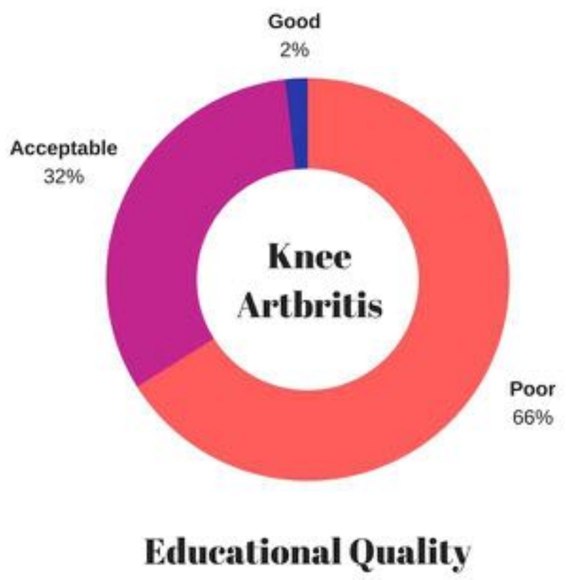
Good
2%
Acceptable
32%
Knee
Artbritis
Poor
66%
Educational Quality

Figure 3

#5688

Progressive Scholarly Acceptance (PSA) Analysis of Global Trends in Robotic Orthopaedic Research: A New Innovation Assessment Metric for Use in Orthopaedic Bibliometric Research

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Introduction and aims:

Robot Assisted Surgery is increasingly proliferative in the international orthopaedic environment. Traditional bibliometric methods poorly assess the impact of surgical innovations such as Robotic technology. Progressive Scholarly Acceptance (PSA) is a new model of bibliographic analysis which quantitatively evaluates the impact of robotic technology in the orthopaedic scientific community.

Methods:

A systematic literature search was conducted to retrieve all peer-reviewed, English language publications studying robot-assisted hip and knee arthroplasty between 1992 and 2017. Review articles were excluded. Articles were classified as either “initial investigations” or “refining studies” according to the PSA model, described by Schnurman and Kondziolka.[1] The PSA end-point is defined as the point in time when the number studies focussed on refining or improving a novel technique (robot assisted arthroplasty) outnumbers the number of studies assessing its efficacy.

Results:

The study identified 73 original studies published since 1992 in the field of robotic arthroplasty. The procedures reported were total hip and total knee replacement, and uni-compartmental knee replacement. Publications originated from 17 countries and 117 organisations. Fifty percent of studies identified were published in the last 5 years at an average of 7 publications per year, compared to an average of 2.7 publications per year from 1992 to 2012. Fifty-eight publications (79.4%) were classified as initial investigations and 15 (20.5%) were classified as refining studies.

Conclusions:

Progressive Scholarly Acceptance model analysis of Robotic Orthopaedic surgery is indicative of a significant increase in published research particularly over the last 5 years. However, the majority of publications are efficacious rather than technique refining. This implies that robotic surgery has not reached the threshold of general acceptance by the Orthopaedic community.

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#6186

Reducing Post-Operative Costs in Elective Total Joint Arthroplasty: A Role for Virtual Care and Telehealth

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Introduction: Unscheduled returns to the emergency room (ER) or urgent care facilities in the post-operative period for total joint arthroplasty (TJA) patients incur substantial costs and require significant healthcare resources to address. Common reasons for these visits include post-operative pain, wound concerns, and medication refills. Virtual care and telehealth models offer surgeons the opportunity to evaluate and treat patients remotely for concerns that arise in the post-operative period. The objective of this study was to retrospectively review unscheduled post-operative visits to our institution's orthopedic immediate care center (I-care) and assess the proportion of visits that were low-acuity and amenable to telehealth or virtual care. The I-care setting serves an alternative clinical site to cater to musculoskeletal complaints and minimize the costs for unscheduled visits that may otherwise present to the ER.

Methods: The I-care orthopedic facility is staffed by an orthopedic resident physician overseen by an emergency medicine attending physician with an on-call orthopedic attending surgeon on standby for escalation of care. The facility is open for patient registrations 8AM-10 30 PM and caters to an average of 25-30 patients per day. Charts from patients that presented to the facility were retrospectively reviewed. TJA patient visits in the 90-day post-operative period were pulled for subgroup analysis. Patient demographics, care category (low-acuity vs high-acuity), estimated costs, and disposition information were collected for each patient. The proportion of patients categorized as low-acuity appropriate for virtual care and telehealth visits was similarly calculated.

Results: Between June 2nd, 2017 and February 2nd, 2017 2,330 patients presented to the I-care facility for musculoskeletal complaints. A total of 126 patients post-op from TJA or revision TJA surgery presented to iCare during this timeframe and a subgroup analysis was conducted on 79 patients presenting in the 90-day post-operative period. The patients were 53.2% female, the average age of 64.1yo +/- 13.5 yrs st.dev and presented on avg post-op day 30.1 +19.7 days. The most common chief complaint were wound concerns (45.6%) followed by pain (26.6%). Of 79 patients presenting within the 90-day post-operative period, 58% were categorized as low acuity and using a computer-based simulation algorithm, 100% of low acuity patients were virtual care eligible. Majority of patients were discharged home (74.7%). Twenty four patients were admitted (24.1%) and one patient required escalation of care to another facility (1.3%). Using cost data from individual patient visits and direct labor costs, an estimated $55,000 USD in savings would have been realized by diverting low-acuity visits to telehealth or virtual care encounters over the nine-month study period.

Conclusions: Telehealth and virtual care present an opportunity to address low acuity patient complaints with minimal cost to the provider and patient. In gainsharing agreements and bundled care models such as the comprehensive joint replacement package, it is advantageous for the health system and treating surgeon to minimize unscheduled post-operative visits. Future study will pilot an existing telehealth and virtual care interface for scheduled and unscheduled post-operative TJA.

#6088

Maximising the Usefulness of PROMs Through ePROMs and PCOMs

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For lower limb joint replacement, there are a variety of surgical techniques and prostheses to choose from, the combination of which result in varying patient outcomes. Current Patient Reported Outcome Measures (PROMs) fail to assess ambition beyond activities of daily living so that it isn't possible to stratify functional performance at the upper end of the scale. Sensitive measures of function are essential for innovators who are trying to deliver an improved functional outcome.

What's more, low linkage rates with other datasets (for instance Hospital Episode Statistics and National Joint Registry data) make it difficult to attribute an outcome to any one activity, and precludes risk adjustment of the data. Thus why it is also difficult to use PROs in performance management, particularly at individual surgeon level when there is insufficient data to draw reliable inferences. There is also a significant time lag between initial collection of Patient Reported Outcomes (PROs) and full reporting which can render the data obsolete.

Electronic-PROM (e-PROM) systems are increasingly being adopted to make PROs more accessible and facilitate greater linkage with other datasets, and Patient Centred Outcome Measures (PCOMs) have been proposed as a way of ensuring that outcomes measured represent each patients' personal goals for treatment.

Furthermore, an alternative role for this data has emerged; to enhance the clinical management of patients. Providing patients and clinicians with real-time access to PROs means that it can be used to facilitate productive conversation during appointments, and support informed and shared decision-making. It may also reduce unnecessary clinic attendance, enabling 'smart' targeted patient reviews.

One such system is JointPRO, which we have piloted at Imperial College NHS Trust and is in use at six other sites. Patient's self-reported health is evaluated using established PROM questionnaires, as well as the Imperial Score, our novel PCOM instrument. The Imperial Score measures an individual's progress towards their goals, and helps inform patient expectation, a key determinant of satisfaction. With heightened sensitivity and patient relevance, the score enables us to determine which interventions are most effective in which patients, including those who aspire to achieve a higher level of functioning (an increasingly representative cohort). JointPRO has also been found to increase the quality of the patient-clinician interaction by focusing the patient's mind on salient issues before the appointment.

Whilst we are cautious of using PROs *in isolation* to inform (-low or -high level) decision making, we have demonstrated that PROs may be used alongside other sources of information to build up a more comprehensive picture of a patient's health and enhance clinical care. The patient-centric nature of the Imperial Score enables us to more sensitively evaluate self-reported health such that we are able to determine which interventions achieve the most value for individual patients in the long-term.

#5641

PROMIS Computer Adaptive Tests Compared With Traditional Patient-Reported Outcome Measures: A Systematic Review

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Background

Orthopaedic surgery aims to improve physical function and quality of life. Evaluation of relevant treatment outcomes is an essential element of evidence based clinical practice. Traditional patient reported outcome measures tend to be lengthy and paper based, thus limiting outcome collection. However, recent adoption of item response theory has resulted in innovative computerised adaptive tests (CATs). Questions are tailored to the respondents' previous answers, thereby eliminating redundant items. Building on the Patient-Reported Outcomes Measurement Information System (PROMIS), which consists of a standardised battery of measures referenced against general population norms, several CATs have been developed to assess a patient's ability or function on a number of health-related domains. This work evaluates clinical evidence for the reliability, sensitivity, validity, and utility of PROMIS CATs for four domains (Physical Function (PF), Pain Interference (PI), Pain Behaviour (PB), and Depression (Dep)) compared with legacy measures, and potential benefits for patients and clinicians.

Methods

A systematic literature review was performed, searching PubMed from inception until the 10th April 2018, using the following terms: (PROMIS[Title/Abstract]) AND CAT. No restrictions were imposed for interventions, comparisons, or language. Of those reviewed, we excluded articles that failed to mention any of the above four PROMIS domains in their title or abstract, together with non-clinical or secondary research, and studies involving only simulated data or children.

Results

One hundred and fifteen articles were reviewed, from which 53 study reports were retained. These covered a broad range of conditions, including upper and lower extremity disorders, and patients undergoing joint replacement surgery. Of the retained articles, 44 (83%) described results obtained for PF, 19 (36%) for PI, 4 (8%) for PB, and 15 (28%) for Dep.

In total, PROMIS CATs were compared against 47 separate clinical outcome measures. Researchers agreed that PROMIS CATs were generally far quicker to administer, typically involving only four to five items and requiring under a minute to complete. The four CATs were shown to have superior reliability to traditional measures and were highly sensitive, with minimal floor and ceiling effects. Included studies provided robust evidence of concurrent validity. Eight out of nine studies comparing the PROMIS-based PF CAT and SF-36 PF scale reported high correlation coefficients (0.72 to 0.86). PF scores were also moderately to highly correlated with AESES scores (0.55 to 0.72) across six studies, and highly correlated with KOOS Sport scale scores (0.72). Five studies compared PROMIS-based PI CAT and QuickDASH, reporting correlations ranging from 0.63 to 0.83. Similar results were found across three studies for the PROMIS-based Dep CAT when compared against CES-D (0.67 to 0.84).

Conclusions

This review provides compelling evidence to support the reliability, sensitivity, validity and utility of PROMIS CATs for research involving a wide range of groups, including patients undergoing orthopaedic surgery. Administration of PROMIS CATs reduces burden on both patients and clinicians, enables remote data collection, and offers a viable alternative to traditional measures of physical function, pain and depression. Strong psychometric properties may help to minimise study sample sizes, reduce research costs, and deliver findings quicker.

#5842

3D Ultrasound: A Novel New Imaging Opportunity for Orthopaedic Surgeons

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Introduction

At present, orthopaedic surgeons utilize either CT, MRI or X-ray for imaging a joint. Unfortunately, CT and MRI are quite expensive, non weight-bearing and the orthopaedic surgeon does not receive revenue for these procedures. Although x-rays are cheaper, similar to CT scans, patients incur radiation. Also, all three of these imaging modalities are static. More recently, a new ultrasound technology has been developed that will allow a surgeon to image their patients in 3D. The objective of this study is to highlight the new opportunity for orthopaedic surgeons to use 3D ultrasound as alternative to CT, MRI and X-rays.

Methods

The 3D reconstruction process utilizes statistical shape atlases in conjunction with the ultrasound RF data to build the patient anatomy in real-time. The ultrasound RF signals are acquired using a linear transducer. Raw RF data is then extracted across each scan line. The transducer is tracked using a 3D tracking system. The location and orientation for each scan line is calculated using the tracking data and known position of the tracker relative to the signal. For each scan line, a detection algorithm extracts the location on the signal of the bone boundary, if any exists. Throughout the scan process, a 3D point cloud is created for each detected bone signal. Using a statistical bone atlas for each anatomy, the patient specific surface is reconstruction by optimizing the geometry to match the point cloud. Missing regions are interpolated from the bone atlas. To validate reconstructed models output models are then compared to models generated from 3D imaging, including CT and MRI.

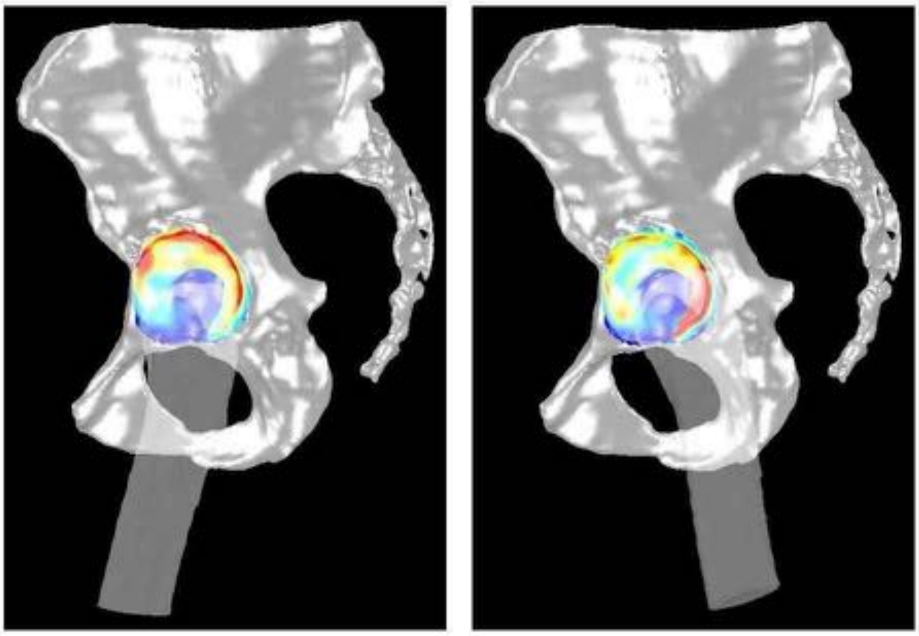
Results

3D ultrasound, which now has FDA approval in the United States, is presently available for an orthopaedic surgeon to use. Error analyses have been conducted in comparison to MRI and CT scans and revealed that 3D ultrasound has a similar accuracy of less than 1.0 mm in the creation of a 3D bone and soft-tissues. Unlike CT and MRI scans that take in excess of 2-3 weeks to create human bones, 3D ultrasound creates bones in 4-6 minutes. Once the bones are created, the surgeon can assess bone quality, ligament and cartilage conditions, assess osteophytes, fractures and guide needles into the 3D joint space. The creation of 3D bones has been accurately assessed for the spine, shoulder, knee, hip and ankle joints. A 3D joint pre-operative planning module has also been developed for a surgeon to size and position components before surgery.

Discussion

3D ultrasound is an exciting new imaging technology available for orthopaedic surgeons to use in their practice. Existing CPT codes are readily available for 3D ultrasound procedures. A surgeon can now evaluate and diagnose bone and soft-tissue conditions, in 3D, using ultrasound, which is safer and is an easier procedure compared to CT, MRI and X-rays. This new ultrasound technology is a highly accurate imaging technique that will allow a surgeon to diagnose bone and soft-tissue concerns in 3D, under weight-bearing, dynamic conditions and guide needle injections to correct location, in 3D.

Figures



a) Stance Phase *b) Swing Phase*

Figure 1: Contact area between femoral head and acetabular cup

Figure 1

Title： Alternative Implant surface coating to extend the implant longevity

Inventors: Weiping Ren, David. C Markel

Problem Statement

Failure of osseointegration and implant infection are the two main causes of implant failure and loosening. There is a definite need for orthopedic implants that promote rapid osseointegration and/or prevent infection, particularly when placed in bone compromised by disease or adverse physiology. Many implant surface fabrication techniques have been developed with the aim of improving osseointegration. For example, Titanium (Ti) implants with hydroxyapatite (HA) coating in cementless hip replacements have been used to enhance bone ingrowth since 1987. The limitations of HA coating include (1) a non-physiological surface of HA coating leads to diminished initial osseointegration; (2) brittle nature; (3) poor adhesion strength and (4) Inability to deliver drugs, such as antibiotics and growth factors. in a sustained pattern.

Our Solutions:

Our goal is to develop functional and biodegradable Ti coatings that can be used as a local drug eluting device. One approach is developing an implant surface nanofiber (NF) coating. A Ti implant surface coated with coaxial doxycycline(Doxy)-doped polycaprolactone/polyvinyl alcohol (PCL/PVA) NFs was prepared during electrospinning. The improved implant osseointegration by NF coatings in vivo was confirmed by SEM, histomorphometry and μCT at 8 weeks after implantation. We further demonstrated that a Doxy-doped NF coating effectively inhibited bacterial infection and enhanced osseointegration in an infected (S. Aureus) tibia implantation rat model. We propose that a coaxial PCL/PVA NF coating doped with Doxy and/or other drugs have great potential in enhancing implant osseointegration and preventing infection *(Biomed. Mater. 12 (2017) 045008).*

Calcium polyphosphate (CPP) is a bioceramic with a polyphosphate chain structure. CPP is biocompatible and biodegradable. We have developed a novel polymeric dicalcium phosphate (P-DCPD) forming cement by the reaction of CPP gel with tetracalcium phosphate (TTCP). P-DCPD is a better ceramic Ti coating than HA because of its unique properties: strong mechanical strength, excellent anti-washout, strong binding to a metal surface, and proven function as drug eluting device with a long and complete release of embedded antibiotics and growth factors. P-DCPD is 100% natural, biodegradable and stimulates new bone formation. Coating Ti with P-DCPD provides a natural and biodegradable substrate and a reservoir for sustained drug release. It is our expectation that this approach will provide solid evidence favoring the advantages of the proposed P-DCPD Ti implant coating over those currently available. We are currently developing and optimizing the coating technologies that can reach a favorable coating performance (thickness, porosity, crystallinity，surface roughness, among others).

PATENTS (PENDING)

(1) Method of making water soluble injectable calcium polyphosphate gels. USA patent application. Ser No# PCT/US 14/45243, filed on July 3, 2014

(2) Method of making injectable cements. USA patent application. Ser No# PCT/US2016/016979, filed on February 9, 2016

PUBLICATIONS

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#5749

Intraoperative Computer Aided Manufacture a Novel Arthroplasty Guidance Approach

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Introduction: Optimal orthopaedic implant position is a major factor to the long term success common joint athroplasty procedures. Many guidance technologies are described such as three-dimensional (3D) printed guide jigs and intra-operative robotics platforms. These technologies enhance implant placement accuracy however high cost, functional limitations, complex logistical chains and inefficient theatre integration hamper their widespread use.

We present a novel intraoperative technology for the rapid intraoperative production of low cost bespoke patient specific guides comprising a tableside robotics platform and sterile disposables. The robotics platform consists of an optical 3D scanner, two and three axis computer numerical control (CNC) actuators, a control computer and fixation points for a sterile drill and drapes. Sterile disposables comprise a guide blank and body of rapid setting biocompatible mouldable material on one surface. In use, a guide wire axis is defined with respect to segmented patient computerised tomography (CT) scan data producing a plan. Intraoperative anatomy is exposed and the guide blank is pressed onto osseous anatomy forming a mould. Once hardened, the guide blank is removed from the patient and inserted into the tableside robot. A 3D optical scan of the moulded surface is recorded and registered with the segmented CT data. The planned guide wire axis is now in the same coordinate frame of reference as the optical scan. The CNC actuators orientate the guide blank and the drill bit such that the drilling axis and position of the drill with respect to the guide blank matches that of the optical scan and planned guide wire axis. A hole is then automatically drilled through the guide blank forming a guide. The guide is removed and placed onto the osseous anatomy, localised by virtue of its moulded surface. A wire may now be driven through the formed hole into bone in accordance with an operative plan.

Objectives: To asses prototype function and accuracy in an ex-vivo simulation of guide wire placement into the glenoid cavity during a total shoulder arthroplasty procedure.

Methods: Computed Tomography (CT) scans of 10 human scapulae were collected, segmented and an optimum glenoid guide wire position was planned and recorded by a surgeon. 10 pairs of scapulae were 3D printed and the surgeon manually inserted guide wires into one of each pair. The prototype device was used to guide wire insertion into the remaining models according to each specific plan. Achieved accuracy was assessed in both the conventional and guided groups.

Results: Average wire placement accuracy was 1.58 mm and 6.82â° degrees in the manual group, and 0.55mm and 1.76â° degrees in the guided group. Guide production took <5 minutes in all cases. The surgeon was satisfied with workflow requirements.

Conclusions: The prototype demonstrates the rapid production of accurate intraoperative guides in accordance with a pre-operative plan. Simple disposable components in conjunction with a compact, non-invasive robotics platform result in potential cost reductions. In addition, improved efficiency and operative workflow help to further overcome the drawbacks of existing guidance technologies. A cadaveric trial is planned to further assess this technology.

Figures

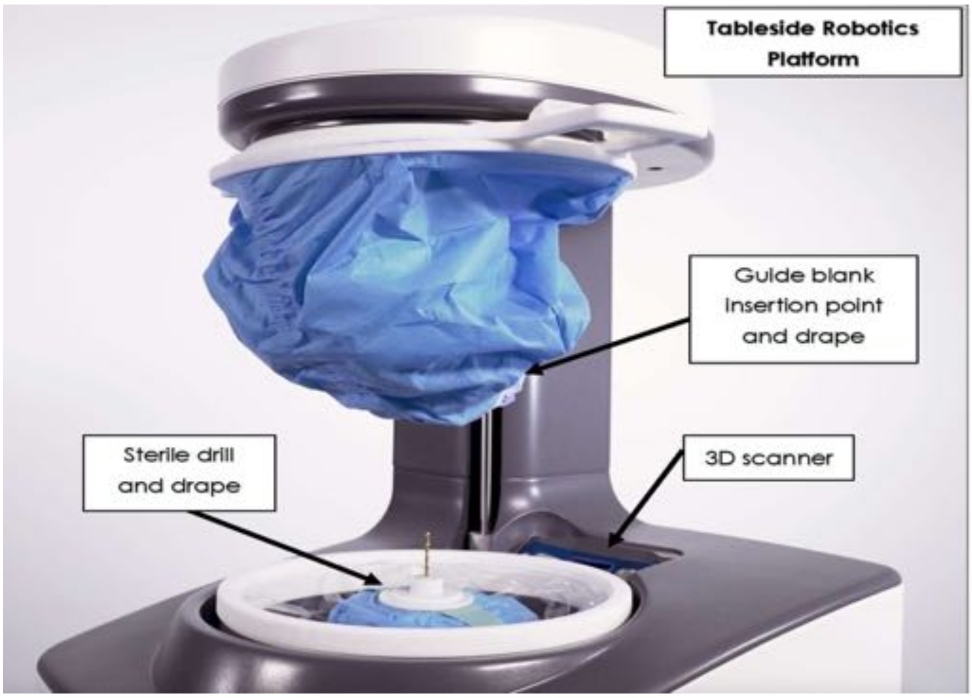

Figure 1

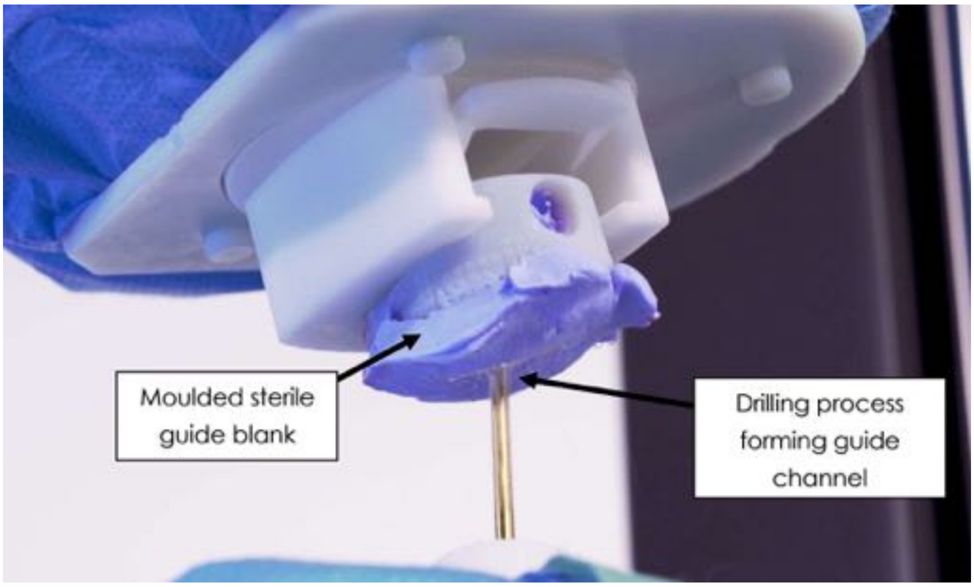

Figure 2

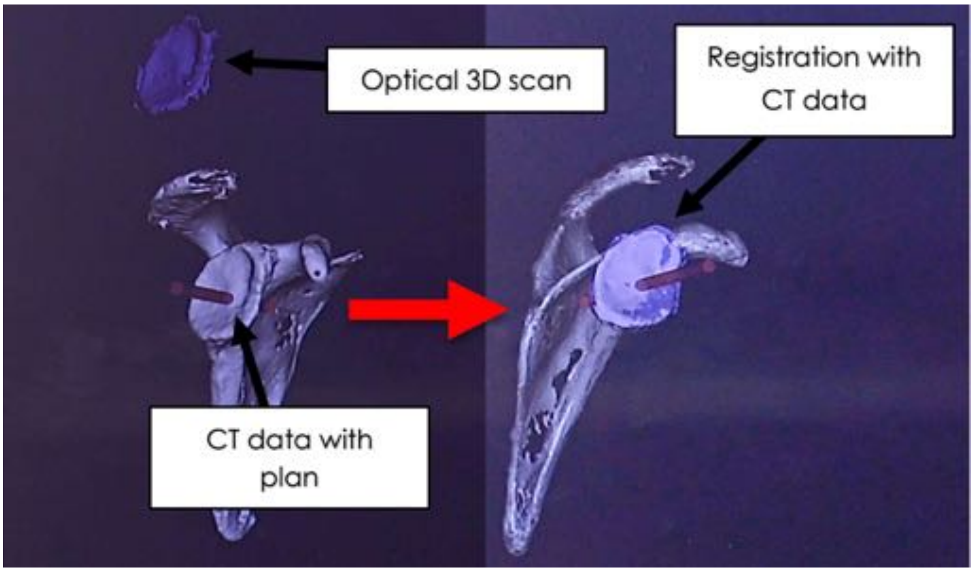

Figure 3

#5857

Novel Sol-Gel Coatings for Local Prophylactic Delivery of Antibiotics on Orthopaedic Prosthesis Materials

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Prosthetic joint infections are a serious complication of arthroplasty surgery and antibiotic prophylaxis is an important line of defence to minimise infection rates. With the increasing numbers of primary joints being performed, the revision burden is growing significantly with infection being a major cause for revision surgery.

With uncemented implants, there is currently no widely available system for local delivery of antibiotics in the way that is routine with antibiotic-loaded bone cement and with increased usage of uncemented prostheses particularly in the field of revision surgery, a source of depot antibiotic would be a very useful adjunct. An appropriate coating technology would offer the possibility of local antibiotic delivery from uncemented prostheses and may help to minimise antibiotic resistance problems by reducing reliance on systemic antibiotics.

We have developed a sol-gel coating system that allows deposition of a thin (up to 10 micron) coating on the material surface for antibiotic delivery. Our previous work with a gentamicin containing coating on hydroxyapatite coated titanium implant material showed that the coating released the bulk of the antibiotic within the first 1-2 h (i.e. within the crucial perioperative period when pathogens may enter the surgical wound) and that the coating was biocompatible with good bone healing in a small animal healing model. Here, we have shown that the coating is compatible with use on tantalum trabecular metal prosthesis material, giving elution of the bulk of the encapsulated antibiotic within 1 h and exceeding the minimum inhibitory concentrations for key target staphylococcal pathogens by more than 100-fold in a laboratory model system. The coating can delivery gentamicin, vancomycin, a gentamicin-vancomycin mixture and potentially other antibiotics, and is compatible with antibiotic loadings of up to 2.5 %. We believe that this system offers the possibility of effective local antibiotic prophylaxis to minimise infection rates in primary and revision hip and knee arthroplasty, as well as with other implantable devices.

OLC - REDUCING THE GUESS WORK IN HIP REPLACEMENT ALIGNMENT.
Orthopaedic Level & Compass System

PROBLEM:

Lewinnek recommended in 1978[1] the 'safe zone' criteria for cup positioning: inclination 40°±10° / version 15°±10°. Many have since published about the difficulty of accuracy when using manual instruments 'by eye'. Factors correlating to mal-positioned cups included surgical approach, surgeon volume and body mass index with increased risk of mal-positioning for minimally invasive surgical approach, low volume surgeons and obese patients[2].

Sub-optimal cup positioning may lead to early damage or failure, restricted R.o.M, patient dissatisfaction and the very traumatic experience of a dislocation. All of this comes with extensive costs for revision surgeries[3], re-admission penalties, possible loss of the hospital's and surgeon's reputation and law suits[4].

Publications still come to light addressing the issue of cup positioning.

- 2010: Only 47% of patients had both inclination and version angles that fell within the optimal range[5].
- 2015: Preferred criteria to be 45°/25° ± 5° and not routinely achievable with currently available manual instruments[6].
- 2016: Surgeons over-estimate operative inclination and under- estimate anteversion[7].
- 2018: Personalized implant positioning surgery[8].

SOLUTION: The OLC has been developed to take the guess-work out yet keeping it easy, quick and simple to operate and also cost-effective. In opposition to high-tech electronic navigation systems it does not require a major financial investment, training, maintenance, electricity, calibration, pre-op CT-scans, bone morphing , storage space or technical in-theatre support.

The OLC comprises of a single design cross-shaped spherical body with pre-set angled holes and a combined bullseye spirit level/compass. Surgical approach depending fixtures connect the cross-shaped body to the cup inserter shaft allowing orientation of the device in line (longitudinal/transverse) with the patient. If the patient is operated in the lateral position and the spirit level/compass is positioned in the hole with the preferred combination of version/inclination angles, the level will confirm the position of the cup. If the patient is in a supine position, the level allows to orientate the cup according to the preferred version angle, whereas the compass is used to control the preferred inclination angle by pivoting the device.

SUMMARY:

- Works with any cup
- Single design for
- Left & Right
- Lateral & Supine
- 30”Accuracy*
- Confirming the cup position while also acting as a warning tool prior to insertion.

Validation tests are scheduled for ‘proof of concept’, level accuracy and the improvements in acetabular cup positioning. Outcomes by summer 2018.

- Patent Pending - Illustration shows prototypes * Data by the manufacturer

Easy – Quick – Accurate – Reproducible – Economical

References:

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3 - Hip Int. 2012 Jan-Feb;22(1):62-7

4 - J Arthroplasty. 2017 Oct;32(10):2958-2962

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8 - EOR Volume 3 03-2018

#5665

Advanced Concept of Bone Implant

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Introduction

An increasing trend in the incidence of primary and revision bone replacements has been observed throughout the last decades, mainly among patients under 65 years old.10-year revision rates are estimated in the 5-20% range, mainly due to peri-implant bone loss. Recent advances allow the design of implants with custom-made geometries, nanometer-scale textured surfaces and multi-material structures. Technology also includes (bio)chemical modifications of the implants' surfaces. However, these approaches present significant drawbacks, as their therapeutic actuations are unable to: (1) perform long-term release of bioactive substances, namely after surgery; (2) deliver personalized stimuli to target bone regions and according to bone-implant integration states.

The Innovative Concept

Here we propose the design of instrumented active implants with ability to deliver personalized biophysical stimuli, controlled by clinicians, to target regions in the bone-implant interface throughout the patients' lifetime (Fig. 1). The idea is to design bone implants embedding actuators, osseointegration monitoring, wireless communication and self-powering systems. This work proposes an advanced therapeutic actuator for personalized bone stimulation, and a self-powering system to electrically supply these advanced implants.

Novel Capacitive Stimulators and Self-Powering Systems

A novel circular capacitive stimulator was designed for personalized stimulatory therapies based on the delivery of electric fields to bone cells (Fig. 2a). Its architecture is composed by 3 coplanar electrodes, 2 mm wide, 1 mm thick, and 0.5 mm apart from each other. It enables the delivery of controllable stimuli, as different stimuli (varying waveform, strength, frequency, etc.) can be delivered to target regions of bone. Numerical biophysical models were developed using COMSOL Multiphysics (v. 5.2) to analyze the osteogenic eï¬€ects of stimulation delivered *in vitro* to MC3T3-E1 bone cells. 8 domains (electrodes, petri dish, substrate, air, cellular medium and physiological medium) were considered to simulate an apparatus to stimulate cell cultures. Simulations were carried out by applying low and high frequency (14 Hz and 60 kHz) sinusoidal excitations, with 10 V of amplitude (electrodes in red: 10 V; electrode in green: 0 V).

A motion-driven and maintenance-free self-powering system was designed using magnetic levitation-based electromagnetic energy harvesting (Fig. 3a). A semi-analytical non-linear mathematical model of its complex energy transduction was developed to estimate the energy harvested during gait patterns.

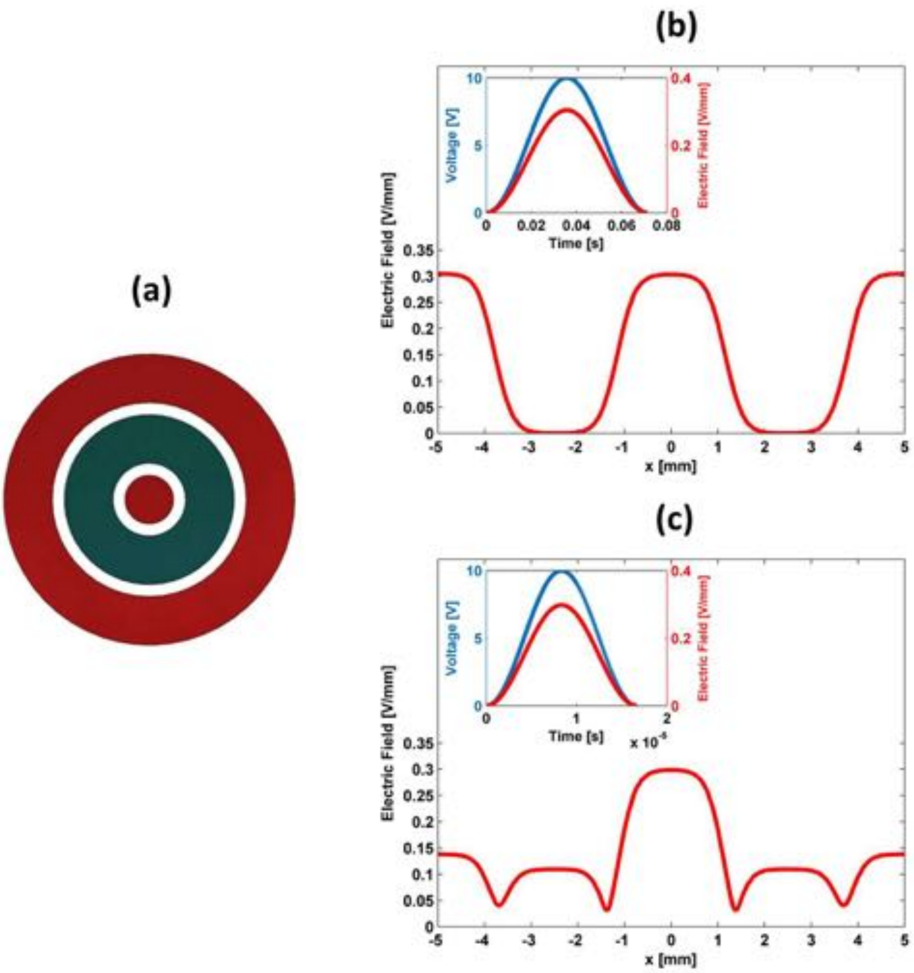
Results

This cosurface stimulator is able to deliver similar magnitude stimuli to bone cells as those already recognized as osteogenic by previous studies. Heterogeneous stimuli is delivered both for low and high excitations, although quite different stimuli distributions are found along the cellular layer (Fig. 3b,c). Maximum stimuli occur over the electrode-anode and its magnitude is approximately 0.3 V/mm. The electrode thickness inï¬‚uence must also be highlighted: the use of electrodes with 0.1 mm thick result in 2.5-fold magnitude increases in high-frequency stimulation.

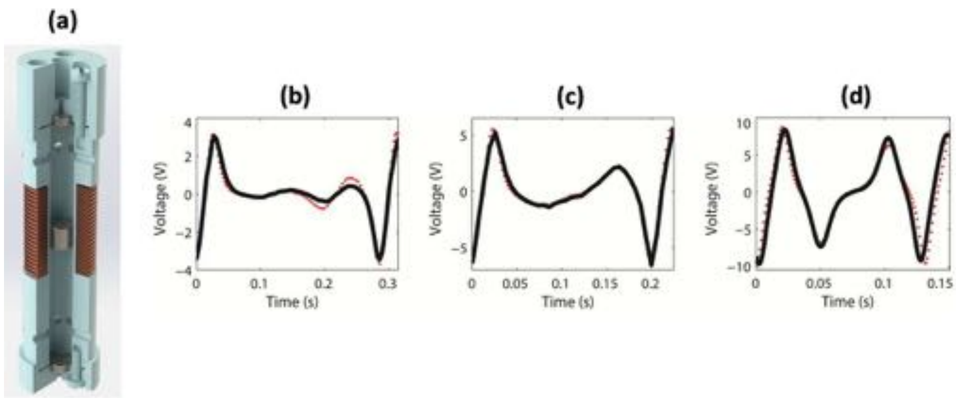
Excellent agreement was obtained between simulation and experiment with mean energy errors around 6% and cross-correlations higher than 85% (Fig. 3b-d for 3.5 Hz, 5 Hz and 7.5 Hz). These results indicate that the design of this self-powering system can be optimized prior to fabrication and according to gait patterns of patients.

Figures

Figure 1



[Figure 2](#)



[Figure 3](#)

#5930

Blood Metal Levels, Leukocyte, and Cytokine Profiles in Patients With a Modular Dual Mobility (MDM) Hip Prosthesis: A Prospective Cohort Study

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Introduction: The purpose of this prospective study was to evaluate the blood metal ion levels and circulating leukocyte profiles and serum cytokines in patients with a modular dual mobility hip implant (MDM) prior to surgery and post-operative follow-up up to 2 years.

Methods: Thirty-ninepatients were enrolled in a prospective cohort study with clinical follow-up up to 2 years. Blood concentration of Cr and Co and serum cytokines were measured. Flow cytometry was used to quantify the subpopulations of leukocytes, including $CD14^+$ and $CD16^+$ monocytes, $CD3^+$ T lymphocytes, $CD19^+$ B lymphocytes, $CD4^+$ Helper T-cells and $CD45^+$RA memory vs naïve T-cells.

Results: There were 15 men and 24 women with a mean age of 61.7±9.0years and mean BMI of 28.4±5.8Kg. Blood Cr levels were normal but detectable in 1 pre-op, 2 year one, and 2 year two patients respectively (range 1-1.3 µg/L, Ref <5.0) **Table 1**. Blood Co levels were detectable in 1 pre-op, 4 year one, and 3 year two patients respectively (range from 1-2 µg/L, Ref<1.0). The percentages of T cells, B cells and subpopulations of T cells were relatively consistent and within normal levels. There was no increase of CD 16+ inflammatory monocytes. As compared to pre-op, a significant reduction of serum levels of IL-5, IL-4, IL-2, IL-10 and IFNγ were observed ($p<0.05$, **Table 2**).

Discussion: Data generated from this prospective single center study demonstrated that the MDM hip implants are safe, as manifested by the stable and acceptable of blood metal levels at 1-2 years follow-up. There was no evidence of activated immune response, as manifested by constant circulating leukocyte profiles. There was a significant elevation in $CD16^+$ between pre-op and year one ($p<0.026$), but the levels reduced by the year two time point and were no longer significantly different than the pre-op measurement. Although the number of T-cells and the subpopulations were not changed postoperatively, the serum cytokine concentrations of IL-2, IL-4, IL-5, and INF-γ were lower at follow-up compared to the pre-operative levels ($P<0.05$). Serum cytokines can be grouped as pro-inflammatory (e.g., IL-1, IL-6, TNFα), anti-inflammatory (e.g., IL-10), or those regulating T-helper (TH) cell function. The latter are subdivided into those associated with TH1 (e.g., IL-2, IFN-γ) or TH2 (e.g., IL-4, IL-5, IL-13) cell function. Because different types of immune reactions to metal ions (e.g., immediate reaction vs. delayed-type hypersensitivity) differentially involve TH1 and TH2 cells, measurement of cytokine production in response to metal ions can potentially give insight into underlying immune mechanisms and responses. The mechanism of down-regulation of both IL-2 and IL-4 as observed in this study warrants further investigation.

Significance/clinical relevance: Our results indicate that the MDM system is safe and presents an opportunity to use a large head and maintain a thick polyethylene-bearing surface. It is especially useful in revisions or higher risk situations when added stability is desired and/or required. The value of serum cytokine profiles in predicting the immune response to MDM implants warrants further investigation.

Figures

Table 1. Results of blood metal ion level and circulating leukocyte profiles

	Pre-Op (n=39)	Year 1 (n=21)	Year 2 (n=21)	Paired T-test Pre-Op Year1	Paired T-test Pre-Op Year2
	Mean ± SD				
Chromium (Cr) (μg/L)	0.54 ± 0.15	0.56 ± 0.17	0.57 ± 0.21		
Cobalt (Co) (μg/L)	0.51 ± 0.09	0.64 ± 0.28	0.62 ± 0.35		
Cell Type (%)					
CD3+ T cell (CD3+CD19-)	74.20 ± 4.89	73.90 ± 6.84	71.10 ± 8.39	0.442	0.085
CD19+ B cell (CD19+CD3-)	11.39 ± 6.47	9.52 ± 5.05	9.96 ± 4.62	0.150	0.210
CD4+ T_N cell (CD45RA+CD197+)	34.05 ± 12.28	30.32 ± 15.08	32.43 ± 19.75	0.429	0.380
CD4+ T_{CM} cell (CD45RA-CD197+)	19.16 ± 8.69	20.82 ± 9.29	16.88 ± 7.52	0.266	0.159
CD4+ T_{EM} cell (CD45RA-CD197-)	36.36 ± 9.84	37.02 ± 14.52	39.78 ± 17.79	0.423	0.186
Effector CD4+ T cells (CD45RA+CD197-)	10.45 ± 8.07	8.84 ± 3.90	11.12 ± 6.75	0.244	0.394
CD14+ classical monocytes (CD14++CD16-)	84.34 ± 8.51	80.11 ± 13.86	81.53 ± 8.23	0.069	0.093
CD16+ intermediate monocytes (CD14++CD16+)	8.29 ± 3.92	12.29 ± 18.50	10.31 ± 4.69	0.026*	0.054
CD14+ non-classical monocytes (CD14+CD16++)	7.35 ± 4.72	7.60 ± 4.84	8.16 ± 5.27	0.430	0.291

T_N, Naive T cells; T_{CM} Central memory T cells; T_{EM}, Effector memory T cells; * p<0.05

Figure 1

Table 2. Results of bead array and blood cytokine level profiles

	Pre-Op Mean ± SD	Year 1 Mean ± SD	Year 2 Mean ± SD	Paired T-Test Pre-Op Year 1	Paired T-Test Pre-Op Year 2
TNFα (pg/mL)	11.21±10.62	10.17±14.79	7.59±4.43	0.077	0.072
IL-5 (pg/mL)	1.56±0.66	1.78±1.11	0.50±0.81	0.214	0.001*
IL-4 (pg/mL)	5.75±5.48	7.00±6.10	1.27±1.83	0.169	0.002*
IL-2 (pg/mL)	4.49±5.01	5.18±4.23	1.24±1.67	0.248	0.043*
IL-10 (pg/mL)	4.56±6.67	5.15±4.04	2.49±1.41	0.361	0.082
IFNγ (pg/mL)	8.50±8.84	9.40±8.83	5.50±1.00	0.333	0.034*

TNF, Tumor necrosis factor; IL, Interleukin; IFNγ, Interferon gamma; * p<0.05

Figure 2

#5730

The Potential Ototoxicity of Cobalt From Metal-on-Metal Hip Prostheses: Preliminary Results

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Background. The past decade, clinical concerns have emerged about metal-on-metal (MoM) hip implants due to increasing failure and revision rates. Several case reports have been published concerning patients with (extremely) elevated blood cobalt (Co) concentrations and signs of systemic cobalt toxicity, clearly related to their MoM hip implant. The clinical image of systemic Co toxicity seems to consist of a variable set of cardiac, endocrine and neurological symptoms, the latter also including tinnitus, hearing loss and vertigo. Considering the known high sensitivity of the auditory and vestibular structures for drug-induced toxicity (e.g. aminoglycosides, cisplatin), this study aims to evaluate the potential toxic effect of cobalt ions from MoM hip prostheses on the auditory and vestibular function.

Method. 20 patients with a unilateral or bilateral MoM hip implant and 20 age- and gender-matched control subjects without MoM implant participated in the study. Each participant was subjected to an extensive auditory and vestibular test battery and a blood sample collection, to determine the blood Co concentration (serum). At this stage, univariate statistical analyses (unpaired t-test and Mann Whitney U, where appropriate) were performed to compare the auditory and vestibular outcome measures between both groups. Multivariate analyses will be conducted in the near future, of which the results will be available by the time of the conference.

Results. The serum Co concentration was significantly higher in the MoM group compared to the control subjects, whose Co concentration all met the reference level for the general population (0.6 µg/l). The majority of the MoM patients had Co levels below the 'safe upper limit' (4 and 5 µg/l for unilateral and bilateral MoM hip prostheses, respectively) used in the local institution. No statistically significant group differences were found for the audiometric as well as vestibular outcome measures, however, some considerable trends are worth mentioning. The audiometric thresholds in the high-frequency range showed clinically relevant differences (≥ 10 decibels) in disadvantage of the MoM group. Moreover, the otoacoustic emission (OAE) amplitude - an objective measure of the cochlear outer hair cell (OHC) function - was considerably lower in the MoM group, again in the high frequencies.

Discussion. Our results suggest that the risk for ototoxic damage induced by cobalt from MoM hip implants is negligible, at least for patients with low Co levels like in our sample. However, recent animal experiments have demonstrated the ototoxic potential of Co, showing a dose- and time-dependent detrimental effect especially on the cochlear OHC and spiral ganglion cells. Most of the audiometric and vestibular outcome measures exhibit a high variability in the normal population, which might explain the lack of statistically significant group differences in this study sample. Consequently, these outcome measures may not be sensitive enough for early detection of subtle Co-induced effects, but a larger sample size is necessary to confirm this hypothesis. Moreover, the abovementioned trends correspond to previous findings regarding drug-related ototoxicity.

#6079

Novel Methodologies for Understanding the Individual Biological Effects of Orthopaedic Wear Particles and Ions

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Currently, different techniques to evaluate the biocompatibility of orthopaedic materials, including two-dimensional (2D) cell culture for metal/ceramic wear debris and floating 2D surfaces or three-dimensional (3D) agarose gels for UHMWPE wear debris, are used. Moreover, cell culture systems evaluate the biological responses of cells to a biomaterial as the combined effect of both particles and ions. We have developed a novel cell culture system suitable for testing the all three type of particles and ions, separately. The method was tested by evaluating the biological responses of human peripheral blood mononuclear cells (PBMNCs) to UHMWPE, cobalt-chromium alloy (CoCr), and Ti64 alloy wear particles.

Methods

Clinically relevant sterile UHMWPE, CoCr, and Ti64 wear particles were generated in a pin-on-plate wear simulator. Whole peripheral blood was collected from healthy human donors (ethics approval BIOSCI 10-108, University of Leeds). The PBMNCs were isolated using Lymphoprep (Stemcell, UK) and seeded into the wells of 96-well and 384-well cell culture plates. The plates were then incubated for 24 h in 5% (v/v) CO_2 at 37°C to allow the attachment of mononuclear phagocytes. Adherent phagocytes were incubated with UHMWPE and CoCr wear debris at volumetric concentrations of 0.5 to 100 μm^3 particles per cell for 24 h in 5% (v/v) CO_2 at 37°C. During the incubation of cells with particles, for each assay, two identical plates were set up in two configurations (one upright and one inverted). After incubation, cell viability was measured using the ATPlite assay (Perkin Elmer, UK). Intracellular oxidative stress was measured using the DCFDA-based reactive oxygen species detection assay (Abcam, UK). TNF-α cytokine was measured using sandwich ELISA. DNA damage was measured by alkaline comet assay. The results were expressed as mean ± 95% confidence limits and the data was analysed using one-way ANOVA and Tukey-Kramer post-hoc analysis.

Results and Discussion

Cellular uptake of UHMWPE, CoCr and Ti64 particles was confirmed by optical microscopy. PBMNCs incubated with UHMWPE particles did not show any adverse responses except the release of significant levels of TNF-α cytokine at 100 μm^3 particles per cell, when in contact with particles. PBMNCs incubated with CoCr wear particles showed adverse responses at high particle doses (100 μm^3 particles per cell) for all the assays. Moreover, cytotoxicity was observed to be a combined effect of both particles and ions, whereas oxidative stress and DNA damage were mostly caused by ions. Ti64 wear particles did not show any adverse responses except cytotoxicity at high particle doses (100 μm^3 particles per cell). Moreover, this cytotoxicity was mostly found to be a particle effect. In conclusion, the novel cell culture system is suitable for evaluating the biological impact of orthopaedic wear particles and ions, separately.

#5905

Metallosis and Tissue Metal Concentrations From Autopsy Retrieved TKA

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Introduction: Little is known about metal release from total knee arthroplasty (TKA). For this study, we asked: what are the concentrations of cobalt, chromium, and titanium in periprosthetic TKA tissue, and which sampling locations have the highest amount of metal accumulation? We also sought to determine a correlation between tissue metal concentration and increased osteolytic cytokine expression.

Methods: 20 TKA systems were collected at necropsy, along with five tissue samples (Figure 1). Tissue samples were digested using a modified method from Kerger et al. [1]. ICP-MS analysis was used to determine the cobalt, chromium and titanium concentrations. For cytokine analysis, synovial fluid was aspirated from 19 donors and was analyzed using a Magnetic Luminex Screening Assay (R&D Systems). The extent of damage to the cobalt chrome femoral condyles was also assessed [2]. Tissues were visually scored for metallosis based on the presence or absence of gray or black discoloration (Figure 2). Spearman rank correlations were performed to determine associations between test variables.

Results: The median metal concentrations were 16 ppb for cobalt (range: 1.3 to 146.4ppb), 46 ppb for chromium (range: 5 to 301.6 ppb), and 9.8 ppb for titanium (range: 0.6 to 98.7ppb). There was no statistical difference between the collection site and the metal concentration. 12/20 (60%) of the necropsy retrieved TKAs had at least one tissue sample that demonstrated metallosis (Figure 2), but there was no correlation between metal concentration and the metallosis score. Increased cobalt was associated with decreased TNFα (ρ= -0.56, p= 0.01) and IL-1β (ρ= -0.48, p= 0.03). Increased chromium concentration was associated with decreased TNFα (ρ= -0.47, p= 0.03), IL-6 (ρ= -0.43, p= 0.04), and MIP-3α (ρ= -0.47, p= 0.03).

Discussion: We were surprised to observe the elevated metal concentrations as well as the high prevalence of metallosis in the periprosthetic tissues from autopsy retrieved TKA. Because metal wear particles may not be visible to the naked eye, our TKA findings are consistent with previous hip retrieval studies [3] that likewise show the visual appearance of retrieved tissues does not accurately reflect their metal content. Metal release was not found to be preferentially collected in periprosthetic knee tissue regions, suggesting that metallic debris may be effectively dispersed throughout the joint capsule [4]. We hypothesized that for TKA patients, the metal concentration in the tissues would be correlated with inflammatory cytokines in the serum. However, our findings did not support this hypothesis, perhaps due to limitations associated with post-mortem synovial fluid analysis or increased cytotoxicity associated with large volumes of metal debris [5]. These overall findings will be useful for the design of prospective revision TKA studies in living patients.

References: [1] Kerger et al. T&EC, 2013; [2] Arnholt et al. JOA, 2015; [3] Ebramzadeh et al. CORR, 2015; [4] Rae et al. Biomaterials, 1986; [5] Bitar et al. WJO, 2015

Figures

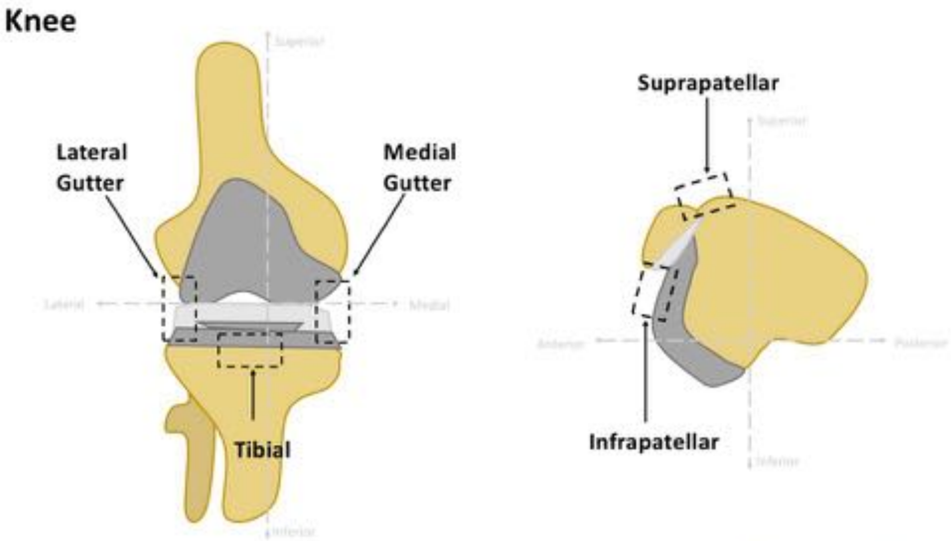

Figure 1: Schematic of total knee joint with identified regions for tissue collection. One tissue sample was chosen from each of the five regions shown within this figure. Each area was chosen because of its proximity to a potential metal release or bearing region of the device.

Figure 1

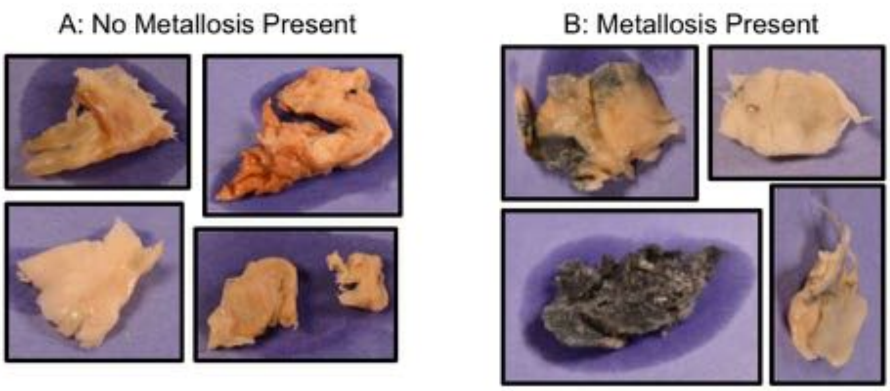

Figure 2: Examples of tissues that demonstrated the binary metallosis assessment used within this study. Tissues in group A were noted as not having metallosis and tissues in group B were noted as having metallosis. Tissues in group B had notable blackening, areas of grey or large visible pieces of metal within them.

Figure 2

#5540

Inflammatory Impact of Metal Ions and Metal Particles in the Synovial Layer of Mice

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Introduction: It is well-known that wear debris generated by metal-on-metal hip replacements leads to aseptic loosening. This process starts in the local tissue where an inflammatory reaction is induced, followed by an periprosthetic osteolysis. MOM bearings generate particles as well as ions. The influence of both in human bodies is still the subject of debate. For instance hypersensitivity and high blood metal ion levels are under discussion for systemic reactions or pseudotumors around the hip replacement as a local reaction. The exact biopathologic mechanism is still unknown. The aim of this study was to investigate the impact of local injected metal ions and metal particles.

Material and Methods: We used an established murine inflammation model with Balb/c mice and generated three groups. Group PBS (control group, n=10) got an injection of 50µl 0.1 vol% PBS-suspension, Group MI (Metal-ion, n=10) got an injection of 50µl metal ion suspension at a concentration of 200µg/l and Group MP (Metal-particles, n=10) got an injection of 50µl 0.1 vol% metal particle suspension each in the left knee. After incubation for 7 days the mice were euthanized and the extraction of the left knee ensued. Followed by immunhistochemical treatment with markers of inflammation that implied TNFα, IL-6, IL-1β, CD 45, CD 68, CD 3, we counted the positive cells in the synovial layer in the left knees by light microscopy, subdivided into visual fields 200x magnified. The statistical analysis was done with Kruskal-Wallis test and a post hoc Bonferroni correction.

Results: The Group with metal particles showed significantly elevated inflammatory markers (TNFα, IL-6, IL-1β, CD 68, CD 45) compared to all other groups. Interestingly, CD 3 as a marker for T-lymphocytes showed no increased levels in all groups. The metal ion group showed significant elevated CD 45 expressions compared to the control group.

Conclusion: The results clearly demonstrate that especially metal wear particles lead to an intensive inflammatory reaction. The tissue formations in the metal particle group show an osseous destructive behavior in previously demonstrated results, comparable to pseudotumors. But, in this study, the expression of the immunohistological markers CD 3, CD 45 and CD 68 indicate that the tissue consists of leucocytes and macrophages, whereas lymphocytes could not be detected. This might be due to an acute inflammatory reaction, whereas the adaptive immune response by T-lymphocytes seems not (yet) to be activated. Overall it must be stated that solid metal wear particles are responsible for local inflammatory reactions, whereas it is still unknown whether wear particles corrode in vivo and release a potentially high level of locally toxic metal ions.

Survivorship of Female Patients Treated With < 48 Mm Metal on Metal Hip Resurfacing: Metal Ions Evaluation at a Minimum Follow-Up of 5 Years

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Introduction:
The aim of this study was to analyze the results of our series of female patients treated with <48 mm MOMHR devices at a minimum follow-up of 5 years, to understand which is the most important aspects affecting the results and to define if the metal ions dosage has to be indicated as a routinely follow-up.

Methods
This is a retrospective clinical study; the cohort included 198 consecutive MOMHR implanted in 181 female patients (17 bilateral procedures). All operations were performed between 2002 and 2011. All operations were performed by the senior surgeon. Indications to MOMHR included primary or secondary osteoarthritis (OA), rheumatoid arthritis and avascular necrosis. Contraindications included poor proximal femoral bone stock (T-score<-2.5sd in BMD of the femoral neck) or severely distorted hip anatomy.All patients were advised to underwent clinical and radiological review with the operating surgeon at 5 weeks, 3, 6 and 12 months postoperatively and then every subsequent 2 years.182 patients answered to our phone calls; 4 patients died (one of them was operated bilaterally) for causes not related to the study, and in 11 cases the phone number was expired.The minimum follow-up was 5.0 years (mean 7.5, maximum 13.2, sd 0.11).

Results
Fourteen devices were revised (7%) in 14 patients: 2 of them were operated bilaterally and the controlateral implant is still fine; thus, the Kaplan-Meier survival rate with revision for any reason as the end point was 92.7% at 13 years (95% confidence interval (CI) 0.9 to 1.0). Revisions data are resumed in table 2.

Main OHS was 44 points (4-48, sd 7);

no statistical relations were found about any aspect about relation between OHS and metal ions dosage (eg Chi Square Analysis p-value = 0.147>0,05 for Score and CR).

Metal ions dosage was performed in only 2 cases before and after the revision (14%); in one case, the Cr dosage was 20 µg/L before and 8 µg/L after surgery; in the other case, the Cr dosage was 100 µg/L before and 10 µg/L after surgery, and the Co dosage was 70 µg/L before and 0.2 µg/L after surgery.

Metal ions dosage was performed in 64 cases of the survived implants (35%). Main Cr dosage was 1.50 µg/L (0.09-7.00, sd 1.70) and main Co dosage was 1.30 µg/L (0.09-9.00, sd 1.60), at a main follow-up from surgery of 5.7 years (0.2-11.0, sd 3.1), in 14 different laboratories. No statistical relation were found between clinical outcomes and metal ions increase.

Conclusions

MOMHR is a good choice for treating severe hip arthritis also in female patients with <48 mm devices. The results are affected especially by surgical technique and indications. The metal ions dosage has to be performed every year for the first two years and then at a larger follow-up.

We believe that additional imaging, such as CT scanning to measure anteversion may better identify the ideal candidate, and specific training with largely experienced surgeons would be mandatory; the metal ions dosage would be used as a monitor of failures.

#6109

Shorter Length of Stay Following THA Associated With Improved Outcomes and Payments Across Medicare Population

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INTRODUCTION:

The transition to a value-based care model has incentivized providers to improve outcomes and decrease costs after Total Hip Arthroplasty (THA). Length of stay after surgery is an important factor both for cost and outcomes of surgery. It is increasingly important to understand if early discharges come at the expense of clinical outcomes and greater financial burdens down the road. In pursuit of that goal, this study seeks to examine the trend of early discharges over a 3.5 year period, and the relationship between length of inpatient stay and 90-day Medicare payments, readmission, and mortality.

METHODS:

Using the Limited Data Set (LDS) from the Centers for Medicare and Medicaid (CMS), we analyzed all primary, elective THA of Medicare patients from January 2013 through June 2016. We calculated and compared length of hospital stay, readmission rate, Medicare Part A expenditures, and morbidity rates for 409,844 THA over a 90-day period. Total Medicare Part A payments were calculated by aggregating payments for anchor stay, home health, skilled nursing, inpatient rehabilitation, long-term care hospitals, outpatient, and readmission.

RESULTS:

In 2013, 5.86% of patients stayed 0-1 days in the hospital after THA; by 2016 20.68% of patients stayed 0-1 days in the hospital. Similarly, the percent of patients staying more than 3 days in the hospital declined from 16.53% in 2013 to 9.08% in 2016. Throughout all years, reduced length of stay is associated with lower expenditure to CMS, lower risk of readmission, and lower risk of mortality.

DISCUSSION AND CONCLUSION:

This study demonstrates that early discharge after THA is becoming more common and is associated with improved clinical and financial outcomes. Hospitals with protocols in place to facilitate early discharge following THA are well-positioned to take advantage of incentive programs in the value-based care environment.

Figures


2013
0-1 days
2 days
3 days
4+ days
5.86%
23.79%
53.82%
16.53%
4.6%
5.3%
7.8%
12.8%
0.28%
0.18%
0.41%
1.56%
$12,430
$15,165
$20,753
$24,766
2014
9.52%
28.14%
48.90%
13.45%
5.2%
5.6%
8.0%
13.6%
0.16%
0.22%
0.43%
1.75%
$12,573
$15,626
$21,490
$25,610
2015
15.22%
32.39%
41.46%
10.93%
4.6%
5.7%
8.3%
14.1%
0.14%
0.25%
0.45%
1.72%
$12,787
$16,076
$22,081
$26,364
2016
20.68%
34.35%
35.89%
9.08%
4.4%
5.5%
8.4%
13.5%
0.18%
0.25%
0.53%
2.00%
$13,416
$16,868
$23,001
$26,847
0% 20% 40% 60%
% of cases for year
0.0% 5.0% 10.0% 15.0%
Readmission %
0.00% 1.00% 2.00%
Mortality %
$0 $20,000
Total cost (adj)

Figure 1

Readmission Rates, Causes, and Costs Following Total Joint Arthroplasty in U.S. Medicare Population

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INTRODUCTION:

In the United States, the Centers for Medicare and Medicaid Services consider rates of unplanned hospital readmissions to be indicators of provider quality. Understanding the common reasons for readmission following total joint arthroplasty will allow for improved standards of care and better outcomes for patients. The current study seeks to evaluate the rates, reasons, and Medicare costs for readmission after total hip and total knee arthroplasty.

METHODS:

This study used the Limited Data Set (LDS) from the Centers for Medicare and Medicaid Services (CMS) to identify all primary, elective Total Knee Arthroplasties (TKA) and Total Hip Arthroplasties (THA) performed from January 2013 through June 2016. The data were limited to Diagnosis-Related Group (DRG) 470, which is comprised of major joint replacements without major complications or comorbidities. Readmissions were classified by corresponding DRG. Readmission rates, causes, and associated Medicare Part A payments were aggregated over a ninety-day post-discharge period for 804,448 TKA and 409,844 THA.

RESULTS:

There were 31,172 readmissions in the ninety days following THA, for a readmission rate of 7.6%. There were 51,768 readmissions following TKA, for a readmission rate of 6.4%. The leading causes of readmission post-THA were revision of hip or knee replacement (17.66%); septicemia (4.76%); and postoperative infections (3.74%). The most common reasons for readmission post-TKA were postoperative infections (6.42%); septicemia (4.84%); and esophagitis (3.85%). In contrast to THA, implant revisions only accounted for 2.51% of readmissions after TKA. The mean cost of readmission post-THA was $11,682, while the mean cost of readmission post-TKA was $8,955.

DISCUSSION AND CONCLUSION:

Ninety-day readmission rates for both THA and TKA remained stable for the duration of the study period, suggesting the need for additional research on the efficacy of various programs intended to reduce the incidence of readmission.

Figures

Readmission Drg Name	Records	% Total	90 day readmiss..
Revision of Hip or Knee Replacement w/ CC w/CC	3,517	10.41%	$20,787
Revision of Hip or Knee Replacement w/o CC/MCC w/o CC/MCC	1,605	4.75%	$16,502
Septicemia or Severe Sepsis w/o MV >96 Hours w/ MCC w/MCC	1,024	3.03%	$12,931
Revision of Hip or Knee Replacement w/ MCC w/MCC	843	2.50%	$29,596
Hip & Femur Px exc. Maj Joint w/ CC w/CC	760	2.25%	$13,032
GI Hemorrhage w/ CC w/CC	716	2.12%	$6,616
Esophagitis, Gastroent & Misc Digest Disorders w/o MCC w/o MCC	710	2.10%	$5,306
Postoperative & Post-Traumatic Infect. w/o MCC w/o MCC	678	2.01%	$7,673
Pulmonary Embolism w/o MCC w/o MCC	611	1.81%	$6,254
Aftercare, Musculoskel Sys & Conn Tissue w/ CC w/CC	606	1.79%	$11,119
Aftercare, Musculoskel Sys & Conn Tissue w/o CC/MCC w/o CC/MCC	595	1.76%	$10,125
Postoperative or Post-Traumatic Infect. w/ OR Px w/ CC w/CC	584	1.73%	$12,861
Septicemia or Severe Sepsis w/o MV >96 Hours w/o MCC w/o MCC	583	1.73%	$7,220
Cellulitis w/o MCC w/o MCC	571	1.69%	$5,642
Kidney & Urinary Tract Infect. w/o MCC w/o MCC	504	1.49%	$6,193
Red Blood Cell Disorders w/o MCC w/o MCC	490	1.45%	$6,626
Heart Failure & Shock w/ CC w/ CC	426	1.26%	$7,962
Complications of Treatment w/ CC w/CC	423	1.25%	$8,912
Cardiac Arrhythmia & Conduction Disorders w/o CC/MCC w/o CC/MCC	420	1.24%	$4,094
Other OR Px For Injuries w/ CC w/CC	420	1.24%	$13,639
Simple Pneumonia & Pleurisy w/ CC w/CC	415	1.23%	$7,926
Cardiac Arrhythmia & Conduction Disorders w/ CC w/CC	377	1.12%	$6,177
Misc Disorders of Nutrition,Metabolism,Fluids/Electrolytes w/o MCC w/o MCC	367	1.09%	$5,730
Renal Failure w/ CC w/CC	357	1.06%	$7,334
Psychoses	353	1.05%	$10,988

Figure 1

Readmission Drg Name	Records	% Total	90 day readmiss..
Esophagitis, Gastroent & Misc Digest Disorders w/o MCC w/o MCC	2,123	3.85%	$5,099
Postoperative & Post-Traumatic Infect. w/o MCC w/o MCC	1,792	3.25%	$6,663
Cellulitis w/o MCC w/o MCC	1,748	3.17%	$5,799
Pulmonary Embolism w/o MCC w/o MCC	1,624	2.95%	$6,180
GI Hemorrhage w/ CC w/CC	1,614	2.93%	$6,541
Septicemia or Severe Sepsis w/o MV >96 Hours w/ MCC w/MCC	1,504	2.73%	$12,460
Septicemia or Severe Sepsis w/o MV >96 Hours w/o MCC w/o MCC	1,164	2.11%	$6,903
Knee Px w/ PDx of Infection w/ CC w/CC	1,114	2.02%	$14,077
Cardiac Arrhythmia & Conduction Disorders w/o CC/MCC w/o CC/MCC	980	1.78%	$3,885
Misc Disorders of Nutrition,Metabolism,Fluids/Electrolytes w/o MCC w/o MCC	946	1.72%	$5,004
Kidney & Urinary Tract Infect. w/o MCC w/o MCC	933	1.69%	$5,344
Renal Failure w/ CC w/CC	908	1.65%	$6,791
Other OR Px For Injuries w/ CC w/CC	838	1.52%	$13,192
Revision of Hip or Knee Replacement w/ CC w/CC	828	1.50%	$20,243
Aftercare, Musculoskel Sys & Conn Tissue w/ CC w/CC	818	1.48%	$8,006
Cardiac Arrhythmia & Conduction Disorders w/ CC w/CC	798	1.45%	$5,688
Psychoses	696	1.26%	$9,612
Red Blood Cell Disorders w/o MCC w/o MCC	676	1.23%	$6,011
Simple Pneumonia & Pleurisy w/ CC w/CC	668	1.21%	$6,818
Peripheral Vasc. Disorders w/ CC w/CC	659	1.20%	$6,745
Heart Failure & Shock w/ CC w/ CC	656	1.19%	$7,029
Hip & Femur Px exc. Maj Joint w/ CC w/CC	618	1.12%	$11,695
Complications of Treatment w/ CC w/CC	602	1.09%	$7,783
Syncope & Collapse	590	1.07%	$4,628
Wnd Debrid & Skn Grft Exc Hand, For Musculo-Conn Tiss Dis w/ CC w/CC	543	0.99%	$19,239

Figure 2

Year of Anc..	Quarter of ..	Anchor Drg ..	Hip Knee An..	Records	% Readmitted
2013	Q1	470	hip	27,479	8.0%
			knee	58,341	6.7%
	Q2	470	hip	27,404	8.1%
			knee	54,122	6.8%
	Q3	470	hip	27,879	7.7%
			knee	55,761	7.1%
	Q4	470	hip	27,567	7.5%
			knee	58,058	6.2%
2014	Q1	470	hip	28,285	7.9%
			knee	58,980	6.3%
	Q2	470	hip	28,818	7.9%
			knee	53,701	6.7%
	Q3	470	hip	28,817	8.0%
			knee	55,676	6.9%
	Q4	470	hip	27,648	7.5%
			knee	53,715	6.3%
2015	Q1	470	hip	29,935	7.4%
			knee	59,700	6.1%
	Q2	470	hip	30,388	7.7%
			knee	55,460	6.7%
	Q3	470	hip	30,462	7.8%
			knee	56,801	6.6%
	Q4	470	hip	30,027	7.1%
			knee	57,303	6.1%
2016	Q1	470	hip	32,685	7.1%
			knee	66,395	5.7%
	Q2	470	hip	32,450	7.1%
			knee	60,435	6.1%

Figure 3

#6110

Association of Technique and Technology With Lower Cost Following THA

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INTRODUCTION:

The introduction of new techniques and technology in medicine has traditionally been associated with higher cost of care. The current study assessed the 90 day cost of hips replaced using the superior hip approach and smart-tool navigation technology compared to other hips replaced during the same period of time in the same geographic region.

METHODS:

Using the Limited Data Set (LDS) from the Centers for Medicare and Medicaid (CMS), we analyzed all primary, elective THA performed in Medicare-insured patients from January 2013 through June 2016 performed in the Commonwealth of Massachusetts. 11,933 elective THA procedures (coded as DRG 470) were performed representing a total expenditure of $290M in Medicare Part A payments (*ie* payments to the acute hospital, long term care hospital, skilled nursing facility, home care, outpatient care, and hospital payments for any readmissions). Payments were subcategorized by surgeon for all surgeons who performed a minimum of 30 THA in CMS insured patients during that time. Surgery performed using the Superior Hip Approach with Smart-Tool Planning and Navigation (HipXpert)[1,2,3] were compared to surgery performed using all other techniques.

RESULTS:

90 day expenditure for hips replaced using Superior Hip Approach with Smart-Tool Planning and Navigation consumed the least amount of cost at 90 days ($18,280) compared to any other THA surgery performed (Figure 1). This represents a decrease of $6,980 compared to the average of $25,260 or 27% less. This also represented a savings of $1310 per episode compared to the second least costly surgeon.

DISCUSSION AND CONCLUSION:

While specific attribution to technique and technology cannot be made given that they were always used together, the current study demonstrates that improved techniques and technology, when applied appropriately, create the opportunity for improved outcomes at a lower cost. The study also clearly demonstrates that new technology is not always associated with higher total cost.

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Figures

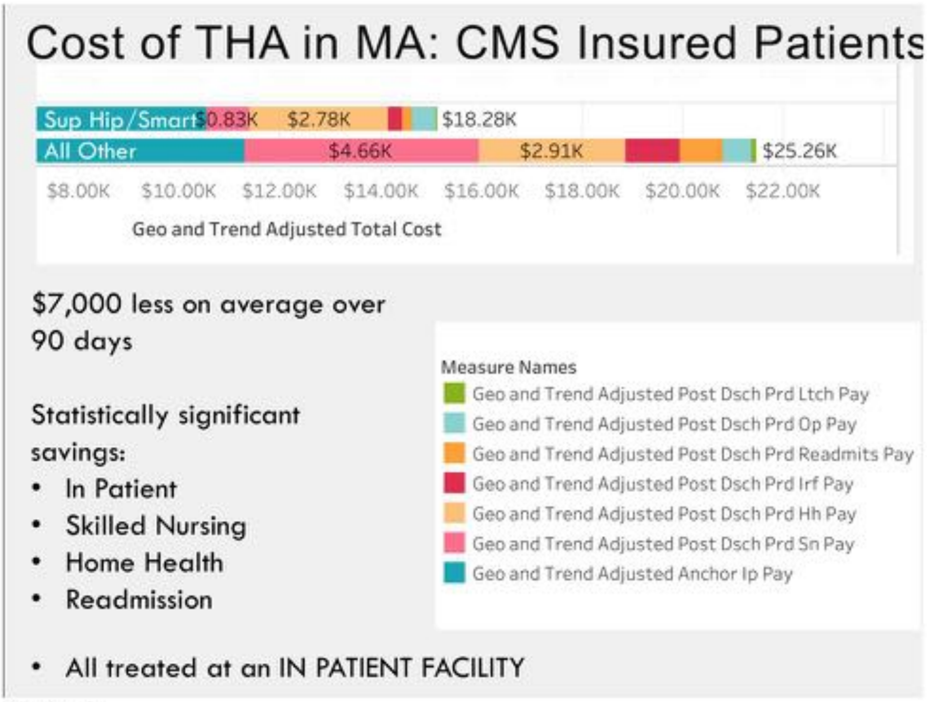

Figure 1.

Figure 1

#5623

Leveraging Your EHR: Data Collection, Clincial Pathways Optimization and Operational Efficiency

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Electronic Medical Records (EMR's) have become the norm for Rehabilitation documentation in both inpatient and outpatient settings. Whether starting with a new EHR or optimizing your current one, utilizing your EMR to its maximum potential has many benefits for Rehabilitation Therapists and supervisors

For Rehabilitation Therapists, using an EHR creates a better continuum of care, reduces redundancies and allows for a single source of truth. For supervisors, valuable data in forms of reports and dashboards assist in staffing decisions, productivity tracking and monitoring of functional outcome measures and clinical pathways.

Proper EHR set up to allow for the ability to capture discrete data fields is crucial. Discrete data provides an objective way of measuring patient progression through clinical pathways and episodes of care, something that could be more subjective in nature. With the shift to EHR's, hospitals, health systems, private clinics, and other health care facilities have the opportunity to enhance how they document and collect data. Providing the infrastructure to collect documented data is vital.

This program will demonstrate how a HIMMS stage 7 acute care hospital with inpatient and outpatient rehabilitation departments has utilized an EHR to meet the needs of our therapists and supervisors.

Specific example to be reviewed are:

Figure 1: Rehabilitation Functional Milestone Achievement Data: Based on surgery type, this tool tracks the average hours for patients to achieve certain functional milestones after joint arthroplasty. This data collection allows us to monitor our performance in accordance with our clinical pathways.

Figure 2: Clinical Pathway Optimization: From our Operational Excellence team, this demonstrates how outcome data was utilized to move from 1 pathway per surgical procedure to 3 different pathways. This allows us to place patients in the most appropriate level of care based on their individual needs and not use a faulty one size fits all model.

Figure 3: Ready for Physical Therapy (PT) Outcomes: Tracks the compliance of the nursing staff documenting that a patient is ready for their post-op PT initial evaluation. This helps to facilitate operational efficiency among multiple disciplines post- surgery to ensure the maximum number of patients are seen in a timely manner.

#6102

The Effects of Robot-Assisted Total Knee Arthroplasty on Readmission and Post-Operative Pain: Are the Added Costs Worth It?

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Background/Introduction

As a new generation of robotic systems is introduced into the world of arthroplasty, Robotic-Assisted Total Knee Arthroplasty (TKA) represents a growing proportion of a reconstructive surgeon's operative volume. This study aims to compare the post-operative readmission rate, pain scores, costs, as well as the effects on surgeon efficiency one year after adoption of these technologies into clinical practice.

Methods

A retrospective chart review was conducted regarding all TKAs performed by a single surgeon after January 1, 2017, the date MAKO Robotic-Assisted TKAs were adopted by a single surgeon at our intuition. All patients over age 18 with a diagnosis of primary osteoarthritis of the knee who underwent TKA during each of this period were identified. Records were analyzed for differences in readmission, mean morphine equivalent, pain scores, operating room (OR) time, and OR charges. For the purposes of statistical analysis the first quarter that Robotic-Assisted TKA were performed (1/1/17 – 3/31/17) was also compared to the same the quarter the following year (1/1/18 – 3/31/18).

Results

A total of 209 patients met inclusion criteria and were included in this analysis. Though the median OR time only decreased form 86 to 80 minutes there was a significant decrease in the range of time it took to complete the procedure (Figure 1). In the first quarter of 2017 OR time ranged from 58 to 113 minutes, while in the first quarter of 2018 the range was only 70 to 91 minutes. Over the same period the median OR charges decreased from $43,338 to $43,124. More importantly, Robotic Assisted TKA were readmitted at a rate of only 2% representing 66% reduction compared to a 4.5% readmission rate for conventional TKAs (Table 1). Interestingly, Robotic Assisted TKAs averaged lower pain scores (2.9) compared to conventional TKA (3.2) which trended towards significance (Table 2).

Discussion/Conclusions

Though early experience with Robotic-Assisted Total Knee Arthroplasty resulted in significant variation in OR time this decreases one year after adopting the technology. One year after implementation Robotic-Assisted TKAs continue to represent an increased cost burden compared to conventional TKAshowever, this may be offset by lower pain scores and more importantly a 66% reduction in readmission rates.

Figures

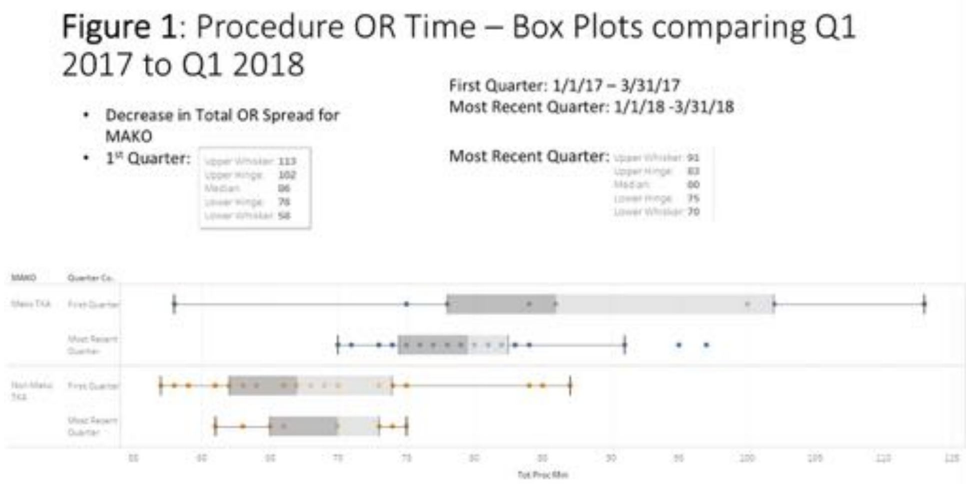

Figure 1

Table 1: Readmission Rates stratified by Elixhauser Admission Risk Buckets

Procedure Type, Risk Category	# of Readmissions	# of Patients	Readmission Rate
TKA with Robotic Assistance	2	98	2.0%
Low	0	7	0.0%
Medium	0	52	0.0%
High	1	33	3.0%
Very High	1	6	16.7%
Conventional TKA	5	111	4.5%
Low	0	1	0.0%
Medium	1	43	2.3%
High	1	50	2.0%
Very High	3	17	17.6%
Grand Total	**7**	**209**	**3.3%**

Elixhauser Admission Risk Buckets - Takes into account the number of Elixhauser Comorbities, number of inpatient/Obs visits in last 2 years, Number of Office/Hospital Outpatient Visits in last 2 years, Number of Emergency Room visits in last 2 years

Figure 2

Table 2: Average post-operative Scores stratified by Elixhauser Admission Risk Buckets

Procedure Type, Risk Category	Avg. Pain Score	# of Patients
TKA with Robotic Assistance	2.9	98
Low	3.0	33
Medium	2.9	7
High	2.8	52
Very High	4.1	6
Conventional TKA	3.2	111
Low	4.5	50
Medium	3.2	1
High	3.0	43
Very High	3.5	17
Grand Total	**3.0**	**209**

Figure 3

90-Day Costs and Clinical Results of Robotic-Assisted and Conventional TKA

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Introduction: Current CMS reimbursement policy for total joint replacement is aligned with more cost effective, higher quality care. Upon implementation of a standardized evidenced-based care pathway, we evaluated overall procedural costs and clinical outcomes over the 90-day episode of care period for patients undergoing TKA with either conventional (Conv.) or robotic-assisted (RAS) instrumentation.

Methods: In a retrospective review of the first seven consecutive quarters of Bundled Payment for Care Improvement (BPCI) Model 2 participation beginning January 2014, we compared 90-day readmission rates, Length of Stay (LOS), discharge disposition, gains per episode in relation to target prices and overall episode costs for surgeons who performed either RAS-TKA (3 surgeons, 147 patients) or Conv. TKA (3 surgeons, 85 patients) at a single institution. All Medicare patients from all surgeons performing more than two TKA's within the study period were included. An evidence-based clinical care pathway was implemented prior to the start of the study that standardized pre-operative patient education, anesthesia, pain management, blood management, and physical/occupational therapy throughout the LOS for all patients. Physician specific target prices were established from institutional historical payment data over a prior three year period.

Results: RAS and Conv-TKA procedures exhibited an average gain per episode of $7,600 and $5,579, respectively (table 1). The average total cost per episode was $2,085 lower for patients receiving RAS-TKA ($28,943 versus $31,028, figure 1), with the majority of cost savings in reduced SNF usage ($1,481) and readmissions ($944), Table 2. Discharge to home versus Sub-acute Rehabilitation Facilities (SAR's) was 14% higher in the RAS group (62% vs 48%, $p<0.05$).

Conclusions: Implementation of a standardized care pathway across all service departments and physicians resulted in a reduction in overall episode of care costs, with further reductions in cost and discharge to SARs observed with the use of RAS.

Figures

Table 1 – WUH BPCI 90 Day Bundle Data – RAS-TKR vs Conventional TKR (7 Quarters 2014-2015)

	Gain/ Episode	Total Gain	LOS (Days)	90 Day Re-Admit	% Home	% SAR
			RAS-TKR Group (3 Surgeons)			
Surgeon A	$ 7,603	$ 927,616	3.4	5 %	66 %	31 %
Surgeon D	$ 8,838	$ 159,084	3.3	11 %	39 %	61 %
Surgeon F	$ 4,292	$ 30,046	4.7	0 %	43 %	57 %
Group Average	$ 7,600	$ 1,116,746	3.4	5.4 %	62 %	37 %
			CONV-TKR Group (3 Surgeons)			
Surgeon B	$ 6,629	$ 245,263	3.5	14 %	57 %	38 %
Surgeon C	$ 6,639	$ 212,444	4.1	9 %	56 %	41 %
Surgeon E	$ 1,033	$ 16,523	3.6	12 %	12 %	88 %
Group Average	$ 5,579	$ 474,249	3.8	11.7 %	48 %	51 %

Figure 1

Table 2 – Breakdown of 90-day episode of care costs

	Robotics[1]	Conventional[2]	Difference
Episodes	147	86	
Anchor Inpatient Stay	$16,802	$16,479	$ 323
SNF	$4,847	$6,327	$ (1,481)
IRF	$440	$609	$ (169)
Home Health	$3,878	$3,652	$ 225
Readmissions	$531	$1,475	$ (944)
Outpatient Physical Therapy	$1,461	$1,424	$ 37
Outpatient/Professional	$985	$1,061	$ (76)
Total	$28,943	$31,028	$ (2,085)

Figure 2

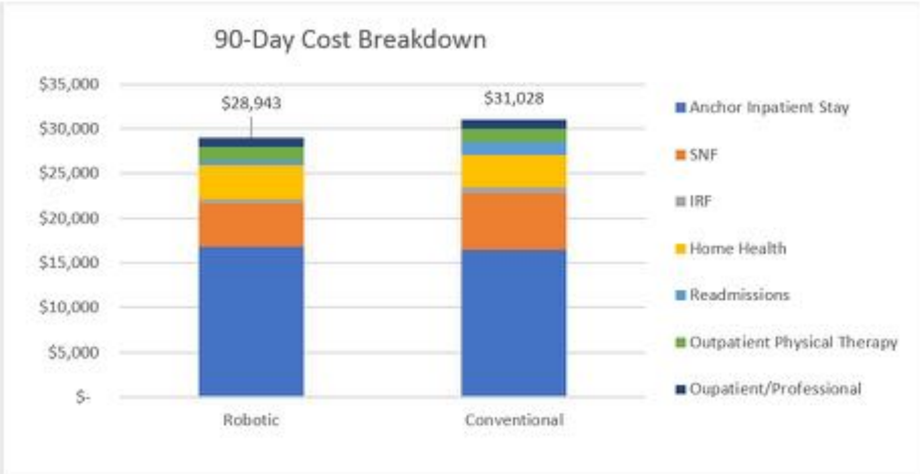

Figure 1 – Robotic-assisted TKR demonstrated an average total cost savings per 90 day episode of $2,085 when compared with conventional instrumentation.

Figure 3

Single-Use Instrumentation in Total Knee Arthroplasty: Safe and Economical

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Introduction

Total knee arthroplasty is a highly effective procedure to improve the quality of life in patients with advanced osteoarthritis. The number of these procedures are expected to grow 174% by 2030. This growth rate is expected to economically strain the health care system. A potential solution to alleviate this problem is the utilization of single use instruments (SUI). Potential advantages of SUI include: improved operating room efficiencies, decreased costs associated with traditional instrument management (sterile processing, shipping), and decreased infection risk. The present study examines the clinical results of SUI compared to standard instrumentation. Furthermore, economic modeling is performed to examine the cost savings that is potentially realized with their use.

Materials and Methods

51 patients receiving a TKA with use of SUI were prospectively compared to 49 patients utilizing standard instrumentation. Knee Society Scores and Radiographic alignment will be evaluated. Adverse events will be recorded.

Economic modeling of SUI will be performed in 4 different areas: 1. Decreased infection burden; 2. Operating room logistics; 3. Sterile processing savings; and 4. Instrument logistical savings.

Results

The average Pre-operative KSS (Objective/Functional) scores were 48.7/41.6 for the SIU patients compared to 50.2/38.7 for the standard instrumentation patients. Post-operative improvements measured 84.0/72.8 and 83.9/76.4 for the 2 groups respectively. The Pre-operative Hip-Knee-Ankle Angle was 176.2 and 177.0 for the 2 groups. The SUI HKA improved to 179.3 while the standard improved to 178.9. There were no statistical differences between the 2 groups. Furthermore, there were no cases of subsidence, migration, loosening, or infection in either group. There were no SUI procedure abandonments.

Economic analysis revealed a decreased risk of Infection burden of $28.08/case. Operating room efficiencies include reduced set-up/take-down time and case efficiency savings/case. This averages $348.14/case. Instrument sterilization savings occur by bypassing the central sterile-processing department completely and models to $700/case. Finally, instrument logistics savings include time and money spent organizing/turning over/shipping instrument sets for cases. This estimate is $112.88/case for a total economic value of $1, 189.10/case.

Discussion

In summary, the present study confirms that SUI provides similar clinical and radiographic results to standard instrumentation for TKA. Furthermore, SUI offers significant cost savings/case via potential benefits of reduced risk of infection, increased operating room productivity, and significant tray sterilization and loaner instrumentation cost savings.

#5714

The Cost-Effectiveness of Dual-Mobility in a Spine Fusion Population With High-Risk of Dislocation

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Introduction: Routine use of DM may not be a cost-effective measure, but an increasing number of THA candidates have coexisting spinal disorders, substantially increasing their risk for instability. This study seeks to expand our understanding of the cost-effectiveness of dual mobility components as an alternative to standard articulations in this high-risk dislocation population.

Methods: A state-transition Markov model with expected-value decision analysis was used to evaluate the cost-effectiveness of DM cups for high-risk patients who would be at high risk for dislocation within one year of their index THA. Direct and indirect costs of dislocation, incremental DM cost ($1000), quality-adjusted life years (QALY) values and dislocation probabilities were derived from published data.

Results: Spine fusion patients were modeled to have a 15% probability of dislocation following primary THA based on published clinical ranges. A hypothetical reduction of 5% in probability of dislocation was deemed clinically plausible with the addition of a DM implant. Under these model parameters, sensitivity analysis was used to identify scenarios for which DM would be cost effective. For example, if the probability of dislocation is 15% with traditional bearings, then the use of DM is cost-effective if it reduces the dislocation risk to 10% and costs less than $640 (Figure 1). However, at its current average selling price ($1000), it would only be cost-effective if it reduces the probability of dislocation from 15% to 7% in this population.

Conclusion: Dislocation is a significant complication and spine fusion patients have been shown to be at high risk. Our results indicate that under specific conditions DM cups are cost-effective for this high risk spine fusion population.

#5689

The Measurement of Limb Length Discrepancy With Full-Length X-Ray Before Total Hip Arthroplasty

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Purpose: Leg length discrepancy after total hip arthroplasty (THA) sometimes causes significant patient dissatisfaction. In consideration of the leg length after THA, leg length discrepancy is often measured using anteroposterior (AP) pelvic radiography. However, some cases have discrepancies in femoral and tibial lengths, and we believe that in some cases, true leg length differences should be taken into consideration in total leg length measurement. We report the lengths of the lower limb, femur, and tibia measured using the preoperative standing AP full-leg radiographs of the patients who underwent THA.

Materials and methods: From August 2013 to February 2017, 282 patients underwent standing AP full-leg radiography before THA. Of the patients, 33 were male and 249 were female. The mean age of the patients was 65.7±9.4 years. We measured the distances between the center of the tibial plafond and lesser trochanter apex (A-L), between the femoral intercondylar notch and lesser trochanter (K-L), and between the centers of the tibial plafond and intercondylar spine of the tibia (A-K) on standing AP full-leg radiographs before THA operation. We examined the differences in leg length and the causes of these discrepancies after guiding the difference between them .

Results: The mean A-L was 674±44 mm on the right and 677±43 mm on the left. The mean difference between the left and the right was 6.2±7 mm. The differences of ≥5 and ≥10 mm between the left and right were confirmed in 131 (46%) and 39 cases (14%), respectively. The mean K-L was 343±23 mm on the right and 343±23 mm on the left, with a mean difference of 4.4±4 mm. The lateral differences of ≥5 and ≥10 mm were confirmed in 88 (31%) and 22 (8%), respectively. The mean A-K was 325±22 mm on the right and 327±22 mm on the left, with a mean difference of 4±4.5 mm. The differences of ≥5 and ≥10 mm between the left and right were confirmed in 24 (9%) and 67 cases (%), respectively.

Discussion: Considering the total length of the lower limbs beyond the little trochanter and the leg length after THA, we confirmed that 46% of the leg length differences of ≥5 mm were admitted to 14%. Thus, THA appeared effective. Perthes head, Crowe classifications 3 and 4, history of childhood paralysis, and so on may be factors for leg length differences beyond the lesser trochanter.

Conclusion: We think that it would be preferable to prepare a preoperative plan to measure leg length after THA by measuring the total length of the lower extremity before surgery and determining the difference between the left and right sides.

Figures

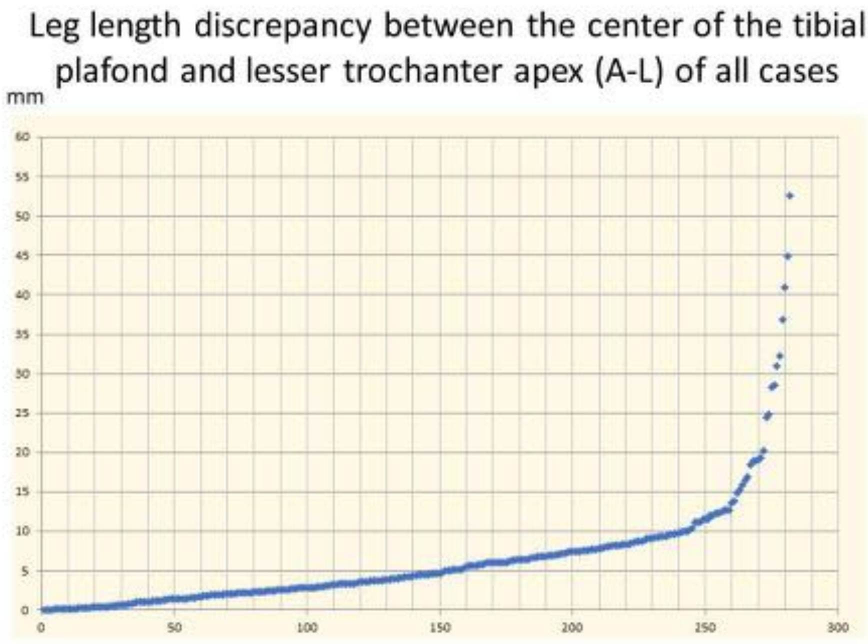

Figure 1

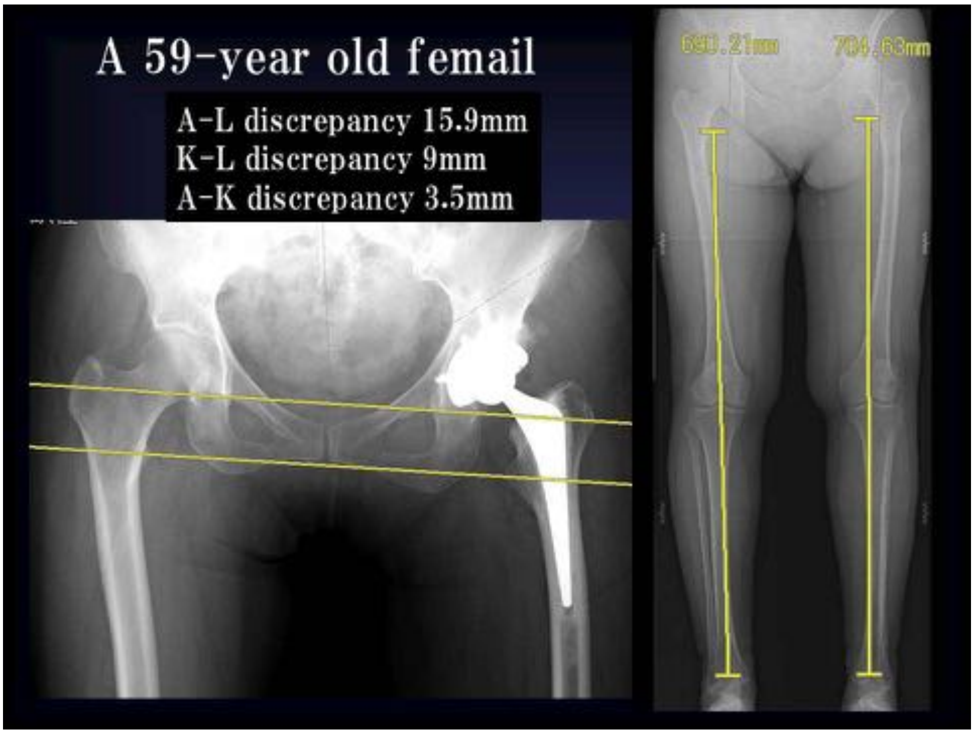

Figure 2


A 71-year old male
A-L discrepancy 24.4mm
K-L discremancy 13.5mm
A-K discrepancy 13.8mm
The patient feels that the left lower limb is longer after the total hip arthroplaty.
697.28mm
722.76mm

Figure 3

#5769

Standing and Sitting Sagittal Pelvic Position : Optimization of Sacral Slope Analysis Using the Relative Pelvic Version Concept.

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Introduction:

Spatial orientation of the pelvis in the sagittal plane is a key parameter for hip function .

Pelvic extension (or retroversion) and pelvic flexion(or anteversion) are currently assessed using Sacral Slope (SS) evaluation (respectively SS decrease and SS increase).Pelvic retroversion may be a risk situation for THA patients .

But the magnitude of SS is dependant on the magnitude of pelvic incidence (PI) and may fail to discriminate pelvic position due to patient's anatomy and the potential adaptation mechanisms : a high PI patient has a higher SS but this situation can hide an associated pelvic extension due to compensatory mechanisms of the pelvic area. A low PI patient has a lower SS with less adaptation possibilities in case of THA especially in aging patients. The individual relative pelvic version (RPV) is defined as the difference between « measured SS » (SSm) minus the « normal SS »(SSn) described for the standard population.

The aim of the study was to evaluate RPV in standing and sitting position with a special interest for high and low PI patients.

Material and methods :

96 patients without THA (reference group) and 96 THA patients were included. Pelvic parameters (SS and PI) were measured on standing and sitting EOS images .

RPV standing (SSm-SSn) was calculated using the formula SSm – (9 + 0.59 x PI) according to previous publications.

SSn in sitting position was calculated according to PI using linear regression :RPV sitting was calculated using the formula RPV = SS – (3,54+ 0,38 x PI).

Three subgroups were defined according to pelvic incidence (PI): low PI <45°, 45°<normal PI<65° or high PI>65°.(fig 1,2,3)

Results :

For THA patients , pelvic parameters were :

SSm standing41° (SD 11° ; 8°.73°)

SSm sitting 25° (SD 12° ;-3°.54°)

SSm variation 16°(SD 11° ; 9°.46°)

RPV standing -2°(SD 9° ; -27°.21°)

RPV sitting 7° (SD 10 ; -15°.29°)

For non THA patients , pelvic parameters were :

SSm standing39° (SD 10° ; 13°.63°)

SSm sitting 17° (SD 11° ;-5°.48°)

SSm variation 27°(SD 13° ; -27°.46°)

RPV standing -1°(SD 7° ; -29°.12°)

RPV sitting 0° (SD 10,5 ; -29.35)

Standing-sitting SS variations and RPV were not correlated with PI.

Low PI incidence patients had very low RPV standing and sitting

In non THA patients RPV standing and sitting were very low.

In THA patients standing-sitting SS variations and RPV were higher than for non THA patients. Sitting RPV was higher than in standing position .

Discussion, Conclusion :

The overall analysis of SS has limitations: higher or lower SS may be linked to 2 factors: pelvic morphology (PI) and sagittal orientation of the pelvis.

RPV and PI were not correlated : a higher or lower value of RPV directly represents the sagittal orientation of the pelvis.

Low PI patients have a specific postural pattern with low pelvic adaptability.

THA patients specificity for RPV needs further studies for understanding the impact on postoperative rebalancing and instability problems.

Figures

Low PI

	Sacral Slope (°)	Pelvic tilt (°)	Pelvic incidence(°)	RPV
Standing	40.7	-1.0	39.7	8.3
Sitting	17.0	24.0	42	4.5

Figure 1

Normal PI

	Sacral Slope (°)	Pelvic tilt (°)	Pelvic incidence(°)	RPV
Standing	43.0	9.6	52.7	2.9
Sitting	27	31	58	8.4

Figure 2

High PI

	Sacral Slope (°)	Pelvic tilt (°)	Pelvic incidence(°)	RPV
Standing	46	20	67	-2.5
Sitting	44	23	67	21.9

Figure 3

#6091

Patellofemoral Evaluation After Total Knee Arthroplasty by Using a Weight-Bearing Axial Radiographic View: Comparison Between Medialized and Domed Patellar Components

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Introduction: We have been re-evaluating patellofemoral alignment after total knee arthroplasty (TKA) by using a weight-bearing axial radiographic view after detecting patellar maltracking (lateral tilt > 5° or lateral subluxation > 5 mm) on standard non-weight-bearing axial radiographs. However, it is unclear whether the patellar component shape affects this evaluation method. Therefore, we compared 2 differently shaped components on weight-bearing axial radiographs.

Methods: From 2004 to 2013, 408 TKAs were performed with the same type of posterior-stabilized total knee implant at our hospital. All patellae were resurfaced with an all-polyethylene, three-pegged component to restore original thickness. Regarding patellar component type, an 8-mm domed component was used when the patella was so thin that a 10-mm bone cut could not be performed. Otherwise, a 10-mm medialized patellar component was selected. Twenty-five knees of 25 patients, in whom patellar maltracking was noted on standard axial radiographs at the latest follow-up, were included in this study. Knees were divided into 2 groups: 15 knees received a medialized patella (group M) while 10 received a domed patella (group D). Weight-bearing axial radiographs with patients in the semi-squatting position were recorded with the method of Baldini et al. Patellar alignment (tilt and subluxation) was measured according to the method described by Gomes et al. using both standard and weight-bearing axial views.

Results: Patients' demographic data, such as age at surgery, sex, and disease were similar for both groups. The average follow-up period was significantly longer in group D than group M (5.4 years vs. 2.5 years, respectively; p = 0.0045, Mann-Whitney U-test). The lateral tilt angle decreased significantly (p < 0.0001, paired *t*-test) from 6.5° ± 2.8° to 1.0° ± 1.2° with weight bearing in group M. However, this parameter in group D changed from 6.7° ± 2.7° to 4.7° ± 3.0° with weight bearing; the difference was not significant. Lateral subluxation also decreased significantly (p < 0.0001, paired *t*-test) from 5.1 mm ± 2.4 mm to 2.5 mm ± 1.4 mm with weight bearing in group M. However, that in group D changed from 2.8 mm ± 2.7 mm to 2.4 mm ± 2.8 mm with weight bearing, and the difference was not significant. On weight-bearing views, patellar maltracking was noted in 4 knees in group D but no knees in group M. The difference was significant (p = 0.017, Fisher's exact test). One of the 21 patients with adequate patellar tracking (4.8%) and 1 of 4 patients with maltracking (25%) complained of mild anterior knee pain.

Discussion: Patellar tracking on axial radiographic views improved better in group M than in group D with weight bearing. The patellofemoral contact area was maintained with a domed patella despite tilting, but not with a medialized patella. Our results indicate that the shape difference affected the degree of radiographic improvement. Thus, the weight-bearing axial radiographic view devised by Baldini et al. is useful for evaluating patellofemoral alignment after TKA, but the shape of the patellar component should be considered for result interpretation.

#5550

Weight-Bearing 3D Foot Model Reconstruction From Simple Standing Radiographs

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Introduction: Although weight-bearing CT of the foot definitely reflects the morphology and deformity of joint, it is hard to obtain the standing CT due to difficulty of availability. Although 3D imaging reconstruction using radiographs has been reported in other joints, there is no study about foot joint. The purpose of this study is to develop a semi-automatic method based on a deformable surface fitting for achieving the weight-bearing 3D model reconstruction from standing radiographs for foot.

Methods: Our method is based on a Laplacian surface deformation framework using a template model of foot. As pre-processing step, we obtained template surface meshes having the average shapes of foot bones (talus, calcaneus) from standing CT images (Planmed Verity) in 10 normal volunteers. In the reconstruction step, the surface meshes are deformed following guided user inputs with geometric constraints to recover the target shapes of 30 patients while preserving average bone shape and smoothness. Finally, we compared reconstructed 3D model to original standing CT images. Analysis was performed using Dice coefficients, average shape distance, maximal shape distance.

Results: The obtained reconstruction model is close to the actual standing foot geometry (Dice coefficients 0.89, average shape distance 0.88 mm, maximum shape distance 6.33 mm). We present the accuracy and robustness of our method via comparison between the reconstructed 3D models and the original bone surfaces.

Conclusions: Weight-bearing 3D foot model reconstruction from standing radiographs is concise and the effective method for analysis of foot joint alignment and deformity.

Figures

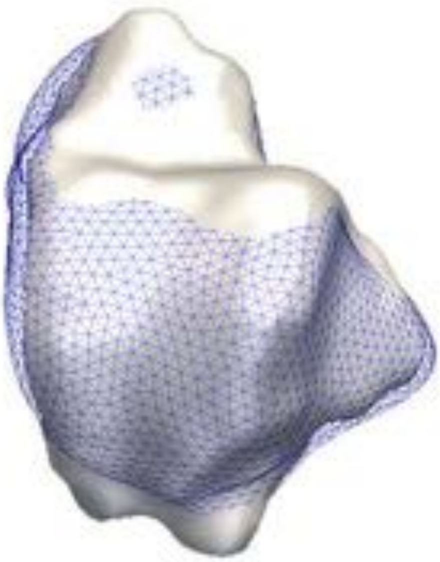

Figure 1

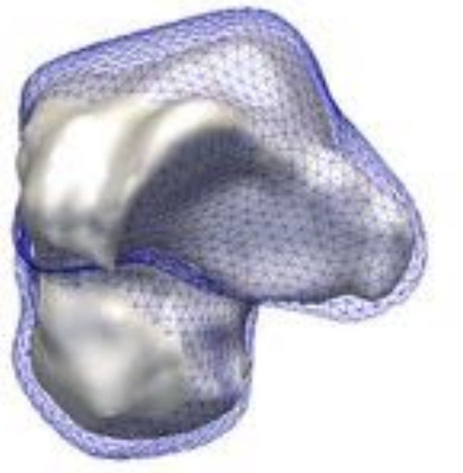

Figure 2

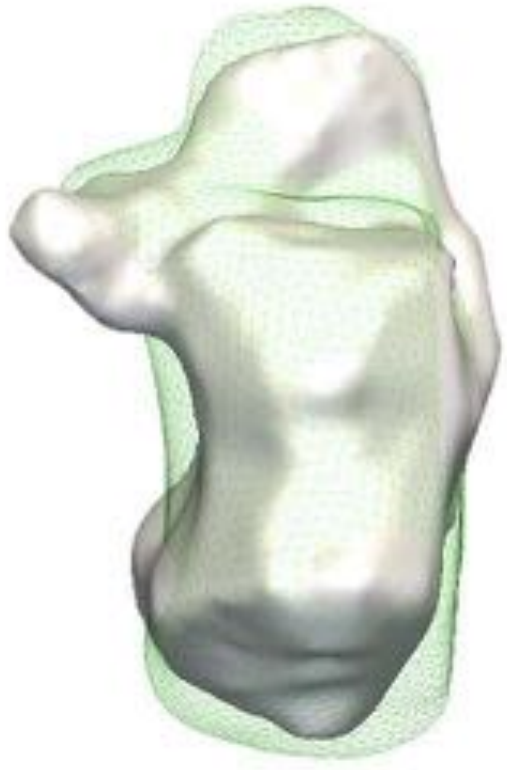

Figure 3

#5579

Long-Term Migration Characteristics of the Corail Hydroxyapatite-Coated Femoral Stem: A 10-Year RSA Study

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Introduction & aims

The magnitude and pattern of acceptable migration in clinically successful cementless stems is not well understood. Radiostereometric analysis (RSA) is a well-recognised method of assessing implant migration.

The aim of this study was to assess the long-term migration characteristics of the Corail hydroxyapatite-coated cementless stem at 10 years using RSA.

Method

A prospective cohort of 30 patients undergoing primary total hip arthroplasty for primary hip osteoarthritis were enrolled into a study to characterise the migration behaviour of a cementless stem. Tantalum markers were attached to the stem and placed in the bone intraoperatively, allowing for RSA measurements to be taken in vivo. Previous 5-year results have been presented.

A total of 14 patients (total 15 hips, one bilateral) with mean age 82 years (range, 69-92 years) underwent repeat long-term RSA radiographs at minimum 10 years post op. The mean time to follow up was 13.9 years (range, 13.3-14.4 years). The RSA radiographs were analysed to assess for implant rotation and translation.

Results

None of the 14 patients (15 hips) followed up have been revised. The migration (rotation and translation) at 6 months, 1 year, 2 years, and 6 years has been described previously.

No stems had additional subsidence of more than 0.25 mm between 6 months and 6 years. The resultant mean subsidence between 2 years and 6 years was 0.03 mm, which is below the limit measurable by RSA.

The long-term, 10-year results, on implant rotation and translation will be presented.

Conclusions

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The Corail stem exhibited variable subsidence within the first 6 months after which there is persistent stabilisation through to 6 years. 10-year results on long-term migration will hopefully reinforce these positive results.

#5932

Pelvic Tilt Cannot Be Accurately Predicted Using Anteroposterior Radiographs

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Introduction: A comprehensive understanding of pelvic orientation prior to total hip arthroplasty is necessary to allow proper cup positioning and mitigate the risks of complications associated with component malpositioning. Measurements using anteroposterior (AP) radiographs have been described as effective means of accurately predicting pelvic orientation. The purpose of our study was to describe the inter- and intra-observer reliability and predictive accuracy of predicting pelvic tilt using AP radiographs.

Methods: Five fellowship-trained orthopaedic surgeons independently analyzed pelvic tilt, within 10 degrees, for 50 different AP pelvis radiographs. All surgeons were blinded to patient information, diagnosis, and correct measurements prior to analysis. Responses were then compared to correct measurements using sitting-standing AP and lateral stereoradiographs.

Results: The average correct predictive value of pelvic tilt between all surgeons was 54%. The intra-observer accuracy of predicting pelvic tilt ranged from 48% to 64%.

Discussion: Pelvic tilt cannot be accurately predicted using anteroposterior radiographs. Pre-operative evaluation of pelvic parameters requires multiple views for detailed assessment. Therefore, lateral radiographs are required for accurate prediction of pelvic tilt.

#5587

NaF-PET Assessment of Postoperative Bone Metabolic Changes Around Total Knee Arthroplasty

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Artificial joint replacement surgery is the orthopedic procedure of choice for the treatment to relief pain, correct joint deformity, and help resume everyday activities. The detailed mechanims regulating peri-implant bone remodeling at the interface remain elusive. Natural postoperative course of bone metabolism in 57 patients (104 joints) with asymptomatic total knee arthroplasty (TKA) was evaluated using ^{18}F-NaF PET/CT. Firstly, we measured total tracer uptake around TKA as total bone metabolism (TBM) and ischial tuberosity was used as a reference tissue for normalization of PET images. Secondly, TBM ratio (TBMR) is calculated by dividing TBM with tracer uptake in reference tissue. A moderate increase in TBMR was observed 4~5 days after implantation and then its intensity thereafter reached the maximum on the seventh postoperative day. There were no differences in TBMR until 12 weeks; then it decreased slowly, returning to the basal levels. The new parameter TBMR and the unique pattern of postoperative metabolic changes in bone around prostheses may help set accurate interpretation criteria to diagnose complications including loosening or infections.

#6066

Assessment of Limb Length and Offset in Total Hip Arthroplasty Using Intra-Operative Digital Radiography

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Background: Obtaining appropriate limb length (LL) and offset in total hip arthroplasty (THA) is critical to patient outcomes and a goal that remains challenging. The present study describes a technique for accurately obtaining target limb length and offset intraoperatively using digital radiography (DR).

Methods: 45 consecutive patients with unilateral hip osteoarthritis undergoing THA were prospectively enrolled over 8 months. All THAs were performed using a soft tissue sparing posterior approach in the lateral decubitus position. Lateral decubitus AP pelvic radiographs were taken intra-operatively using standard adjustments for rotation and tilt to obtain a standard AP image. Targeted corrections for LL and offset were set for each individual patient based on the severity of the disease as well as the presumed normal anatomy on the contralateral hip. LL (vertical distance from inter-teardrop line to the lesser trochanter), offset (distance between ischium and femoral calcar), canal fit and orientation were measured. Adjustments were made until the target LL and offset was achieved along with stable range of motion and impingement testing.

Results: On post-operative AP supine pelvis radiographs, LL and offset were obtained within 5mm of the targeted goal in 100% of patients. Interestingly, on final AP pelvis images, 91.1% of patients were within 5mm of the limb length of the opposite limb. The 8.9% greater than 5mm different were done purposefully based on the patient's anatomy. Target femoral component positioning (varus/valgus) and size (fit) was obtained in 100% of patients. No patients had complaints of limb length discrepancy at 2 year follow up.

Discussion and Conclusion: DR is an accurate measurement tool for intra-operative assessment of LL, offset and femoral component positioning and sizing. Based on our results, target LL should not be confused with equal LL as 'equal' does not mean 'normal' for many. Together with range of motion/impingement testing, DR can help surgeons achieve excellent radiographic and clinical outcomes.

#5697

Efficacy of Regional Adductor Canal Block Using Extended Release Liposomal Bupivacaine in Total Knee Arthroplasty: A Randomized Prospective Study

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Background: Exparel (Pacira Pharmaceuticals, Parsippany, NJ, USA) is a long-acting liposomal Bupivacaine extended release compound that can be used as peri-articular injection (PAI) or regional nerve block. The purpose of this study was to compare the post-operative analgesic efficacy of Exparel as a single administration adductor canal block (ACB) varsus PAI.

Methods: From May 2016 to June of 2017, 70 patients with primary knee osteoarthritis undergoing unilateral knee replacement were prospectively randomized into two cohorts: 1) PAI (Exparel 266 mg (20 ml vial) with 20 ml of 0.5% bupivacaine HCl, and normal saline to a total volume of 120 ml); 2) ACB (Subsartorial saphenous nerve usingExparel 266 mg in 20 ml vial). All patents underwent spinal anesthesia with comprehensive pre-emptive and postoperative multimodal pain protocol. All opioids given were converted to morphine equivalents. Pain was recorded at 4 - 12 hrs (day of surgery), post-operative day (POD) 1, 2, and 3 after surgery.

Results: There was no statistical significance between the pain scores during the first 12 hrs (day 0) after surgery. We found a trend towards a significance on POD # 1, as PAI group had less pain (5.3 vs 4.2, p=0.09). The mean pain score in ACB group increased on POD # 3 while in PAI continued a decrease (4.8 vs 1.8, p=0.03). There was no statistical significance between the 2 groups regarding the accumulative daily converted Morphine equivalent consumption or total consumption.

Conclusion: We found similar results between PAI and ACB using Exparel after TKA up to 48 hours.

#5599

Accelerated Rehabilitation After TKA. a French Nationwide Study.

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INTRODUCTION

The optimal course of post-operative rehabilitation after total knee arthroplasty (TKA) is debated. Accelerated processes have been developed in order to facilitate the rehabilitation, to shorten the duration of hospital stay and to improve the final functional result. However, the exact indication and limits are not clearly defined. The goal of this study was to assess the indication, limits and possible difficulties of accelerated rehabilitation programs in a multicentric analysis at a nationwide level.

METHODS

A prospective, observational study was conducted at a national level. All participating centers were selected on a voluntary basis. All centers had previously implemented an accelerated rehabilitation program, and no attempt was made to change this program for the purpose of the study. The selection criteria for participating to an accelerated rehabilitation program were early deambulation (<24h) and home discharge.

All patients undergoing TKA in the participating centers between October 2016 and October 2017 were eligible for this study. Patients operated for unilateral primary TKA with an accelerated rehabilitation program were selected. Usual demographic and peri-operative items have been recorded. All patients were contacted after 1 year for repeat clinical and radiological examination (KSS, Oxford knee questionnaire and knee plain X-rays). Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information. Attention was paid to collect all clinically relevant difficulties and all complication, especially those related to the accelerated rehabilitation program.

RESULTS

839 patients were included: 314 men and 525 women, with an average age of 70 ± 10 years, and an average body mass index of 30 **±** 6 kg/m². Patients not entering the accelerated rehabilitation program after surgery were mainly people who were living alone at home. Mean length of stay was 4.4 days for all cases, and 566 patients (67%) were discharge home after a mean length of stay of 3.9 days. No complications related to the short length of stay was observed. 22 patients (3%) needed a phone call following discharge. 33 patients (4%) had an early repeat hospitalization. 29 patients (3%) were reoperated. A significant improvement was observed for both KSS and Oxford knee questionnaire between baseline and the 3 months follow-up. Mean KSS increased from 107 to 178 points. Mean Oxford knee questionnaire score increased from 36 to 51 points.

No difference was observed between the rehabilitation of the different centers. No difference was observed between teaching hospitals and general hospitals. No difference was observed between centers according to the number of procedures. No difference was observed between centers located in big urban regions and more rural centers.

DISCUSSION

Accelerated rehabilitation program should be the default post-operative course after TKA.

#5729

Post-Operative Day Zero Physical Therapy Contributes to Faster Physical Recovery and Cost Effectiveness for Total Hip Arthroplasty Patients

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INTRODUCTION: Physical therapy(PT) is an integral component in the management of musculoskeletal conditions. On the other hand, there have been few reports exclusively dedicated to studying PT interventions on the same day of total hip arthroplasty(THA). In this study, we investigate the role of rehabilitation in the early postoperative period on length of stay (LOS), total medical cost, and physical recovery following total hip arthroplasty.

METHODS: A prospective cohort study was carried out 104 consecutive patients who underwent 107 primary THA performed by two surgeons. Data were gathered on all patients who underwent operative management from June2016 to June 2017. Institutional review board approval was obtained before performing this study. Patient demographic, physical, and clinical dates were collected for all patients, including age, gender, body mass index (BMI), diagnosis, Japan Orthopedic Association (JOA) hip score, Japanese Orthopedic Association Hip-Disease Evaluation Questionnaire (JHEQ) score, 3min walk test, and Timed up and go (TUG) test. The patient population consisted of 5men and 99women, with an average age of 66.0 years (range, 50-84 years). There were no statistically significant differences between patients who did and did not receive PT with regard to demographic, medical, and surgical data, including gender, age, BMI,JOA hip score, JHEQ score, preoperative 3min walk test, preoperative TUG test(Table 1). All patients underwent direct anterior approach THA through navigation system. Postoperative day (POD) 0 was defined as the same day of surgery. There were no standardized criteria by which patients were selected for participation in rehabilitation with physical therapists. Patient selection for POD 0 rehabilitation was based on the end of surgery time. For instance, when the end of surgery time was in the forenoon, the patients were received POD 0 PT. In contrast, patients who ended operation in the afternoon were classified POD 1 PT. Rehabilitation protocol was adjusted based on surgical approach, and all patients were weight bearing as tolerated. TUG test and 3min walk test was done by a physiotherapist on the seventh day postoperatively.

RESULTS: Patients who received PT on POD 0 were compared with patients who received PT on POD 1. (Table2) Using the operative start time to determine LOS, patients who received therapy on POD 0 stayed an average of 14.1±4.8 days, and those who received therapy on POD 1 stayed an average of 19.2±9.1 days. The LOS was statistically significantly different between groups (P = .01). In terms of physical recovery, the TUG test received therapy on POD 0 was taken an average of 14.0±6.0 seconds, and the TUG test received therapy on POD 1 was an average of 17.6±9.4 seconds. (P=.04) Furthermore, Total cost on POD0. Day 0 patients had a mean cost of ¥1,970,000±21,000 and Day 1 had a mean cost of 2,190,000±49,600, which remained significance difference(P=.01)

CONCLUSION: This study suggests that early rehabilitation and patient mobilization on the date of surgery is important to shorten length of hospital stay, decrease total medical cost and to achieve faster physical recovery.

Figures

Table1. Demographic, phiysical and clinical characteristics of patients received PT in Total Hip Arthroplasety

	POD 0 PT	No POD 0 PT	*P value*
No. of Patients	54	50	
No. of Joints	56	51	
Sex, n(%) female	86	83	0.95
Age (y)	66.0±11.0	66.0±12.4	0.96
BMI (kg/m^2)	24.1±4.7	24.6±4.4	0.6
JOA hip score	39.6±13.0	36.2±11.8	0.15
JHEQ hip score	20.5±11.7	20.2±12.3	0.89
3min walk test(m)	143±50.6	144±50.2	0.89
TUG test(s)	15.5±9.9	15.2±0.2	0.87

Abberivations : BMI,body mass index; JOA hip score, japan orthopedic association hip score; JHEQ, Japanese Orthopaedic Association Hip-Disease Evaluation Questionnaire; TUG test, Timed up and go test

Table 2. Ellement related to PT timing

		Physical therapy		
	Evaluation day	POD 0	No POD 0	*P value*
3min walk test (m)	POD7	143.4±51.3	144.2±65.0	0.95
Timed up and go test (second)	POD7	14.0±6.0	17.6±9.4	0.04*
Length of Stay (days)		14.1±4.8	19.2±9.1	0.01*
Total Cost (¥)		1,970,000±21,000	2,190,000±49,600	0.01*

Figure 1

#6022

Feasibility of Using a Surface Sensor to Measure Activity Specific Outcomes After Total Knee Replacement

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Background:

Total Knee Arthroplasty (TKA) provides patients with significant improvements in quality of life. Subjective patient reported outcome measures (PROMs) are traditionally used to measure preoperative functional status and postoperative outcomes. However, there are limitations to PROMs. In particular, they provide virtually no functional information in the first 3 weeks after surgery, which could be used to guide the patient’s recovery. Newly available wearable electronic sensors make it possible to: 1) measure important functional outcomes following TKA; 2) guide the patient’s physical therapy (PT); and 3) provide real-time functional and clinical information to the provider.

Compliance with PT after TKA is a challenge. Patients cite time, transportation, and cost as deterrents to PT appointments. However, an intensive PT program is essential in TKA. Surface sensor devices may be able to increase PT compliance by guiding patients through exercises at home. Additionally, these devices can transmit PT progress in real-time to the providers, allowing them to monitor and assist the patient’s recovery.

Our study investigates the feasibility of using a surface sensor device (TracPatch™) on patients following TKA. We sought to answer the following questions: 1) Will patients tolerate the device; 2) Will patients comply with device instructions; 3) Will patients be able to use the smart phone application; 4) Will the device collect, transmit, and store data as it was designed? We believe these fundamental questions must be answered as we enter the era of personal sensor-measured functional outcomes.

Methods:

20 patients undergoing primary, unilateral TKA were enrolled in this IRB approved study. At the pre-surgical visit, patients were given instructions for the device and smart phone application. Each patient used the device in the week prior to surgery, and data was collected. The device was again applied in the operating room. For 3 weeks post-operatively, the device collected functional data, along with WOMAC, OKS, KSS, PROMIS, and VAS pain scores. A satisfaction survey was collected on the device.

Results:

The study results emphasize the importance of clear device instructions. Using the sensor and phone application prior to surgery was very helpful. The device was surprisingly well tolerated. Older patients were able to use the device without significant difficulty. Virtually all patients found the device helpful and, often fun. Physical therapists felt that the devices helped personalize the therapy program. The functional information from the device was much more helpful in guiding care in the first 3 weeks following surgery than PROM scores.

Conclusion:

It is anticipated that sensor devices of the kind tested in this study will have a major impact on the care of TKA patients. The purpose of this study was not to measure that impact. Our goal was to examine the factors that optimize the use of these devices. It is critical that clear device instructions be given to patients. Office procedures must be established to monitor use of the devices. If protocols are established for their use, surface sensors have the potential to provide invaluable information to TKA patients and caregivers.

#6166

A Pilot Study on Fracture Detection Using Vibration Frequency Analysis During Powered Impaction of THA

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Introduction

In cementless THA the incidence of intraoperative fracture has been reported to be as high 28% [1]. To mitigate these surgical complications, investigators have explored vibro-acoustic techniques for identifying fracture [2-5]. These methods, however, must be simple, efficient, and robust as well as integrate with workflow and sterility. Early work suggests an energy-based method using inexpensive sensors can detect fracture and appears robust to variability in striking conditions [4-5]. The orthopaedic community is also considering powered impaction as another way to minimize the risk of fracture [6-8], yet the authors are unaware of attempts to provide sensor feedback perhaps due to challenges from the noise and vibrations generated during powered impaction. Therefore, this study tests the hypothesis that vibration frequency analysis from an accelerometer mounted on a powered impactor coupled to a seated femoral broach can be used to distinguish between intact and fractured bone states.

Methods

Two femoral Sawbones (Sawbones AB Europe, SKU 1121) were prepared using standard surgical technique up to a size 4 broach (Summit, Depuy Synthes). One sawbone remained intact, while a calcar fracture approximately 40mm in length was introduced into the other sawbone. Broaching was performed with a commercially available pneumatic broaching system (Woodpecker) for approximately 4 secs per test (40 impactions/sec) with hand-held support. Tests were repeated 3 times for fractured and intact groups as well as a ‘control’ condition with the broach handle in mid-air (ie not inserted into the sawbone).

Two accelerometers (PCB M353B18) positioned on the femoral condyle and the Woodpecker impactor captured vibration data from bone-broach-impactor system (Fig1).

Frequency analysis from impaction strikes were postprocessed (Labview). A spectrogram and area under FFT (AUFFT) [4] were analysed for comparisons between fractured and intact bone groups using a nested ANOVA.

Results

Vibration frequency patterns between respective groups were best observed using an accelerometer positioned on the impaction device rather than on a sawbone (fig1). Qualitative assessment revealed that spectrograms showed no obvious difference for characteristic vibration frequencies between intact and fractured bone groups. A frequency signal at approximately 10kHz was absent for control impactions but present with bone impactions (Fig2). Quantitative assessment revealed AU-FFT was noticeably higher for intact bone groups than fractured bone groups for sampled impactions using a nested experimental design for statistics (p=0.11).

Discussion

Our pilot study demonstrates that application of powered impaction combined with vibration frequency analysis has the potential to distinguish between an intact and fractured sawbone in a way that minimises instrumentation footprint and complexity of workflow in OR with a new generation of impaction device targeted at reducing and detecting bone fractures. Further investigation should validate these methods by evaluating the variation with sawbones and simulated bone fractures.

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Figures

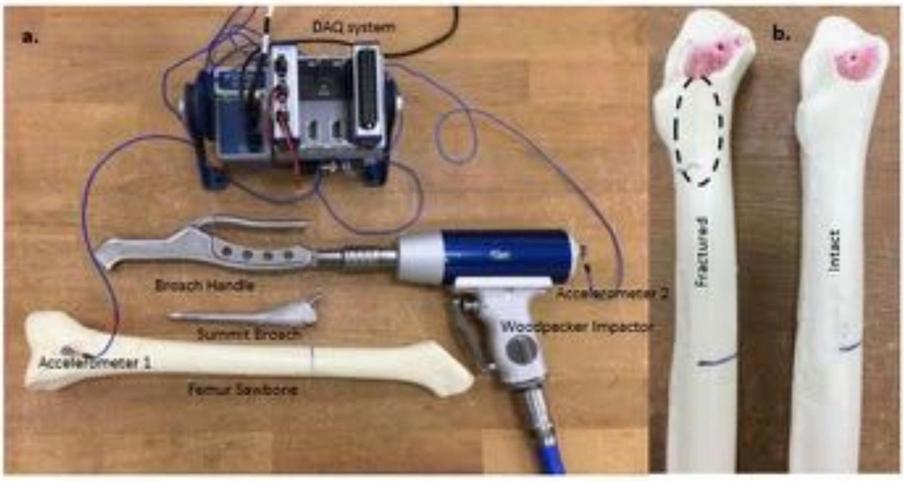

Fig1: Illustration of a.) experimental set up for powered impaction with a woodpecker pneumatic hammer. An NI DAQ 9232 was used for data acquisition; b.) fractured and intact sawbone states. Horizontal markings approximately 10mm below the lower trochanter were used to indicate the position for hand grip support

Figure 1

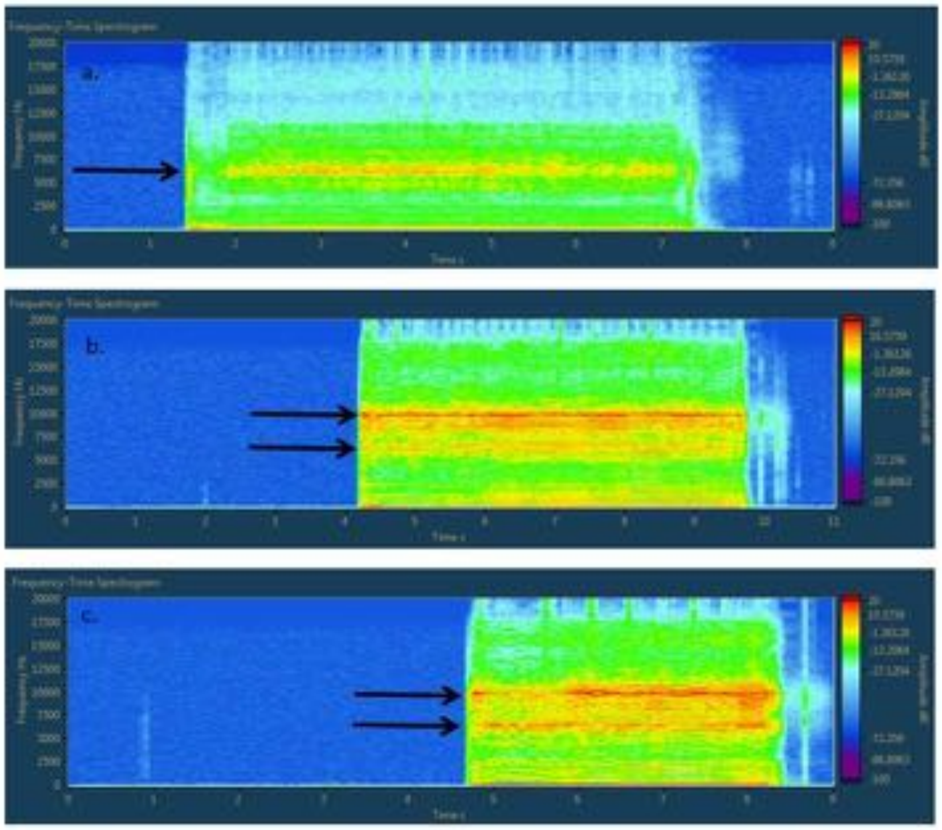

Fig2: Typical frequency-time-amplitude spectrograms from individual powered impaction events for a.) control (n= 157 impactions), b.) fractured (n= 191), and c.) intact (n=149) test groups. Data shown from accelerometer on powered impactor. Arrows shown indicate the characteristic frequencies for each test group

Figure 2

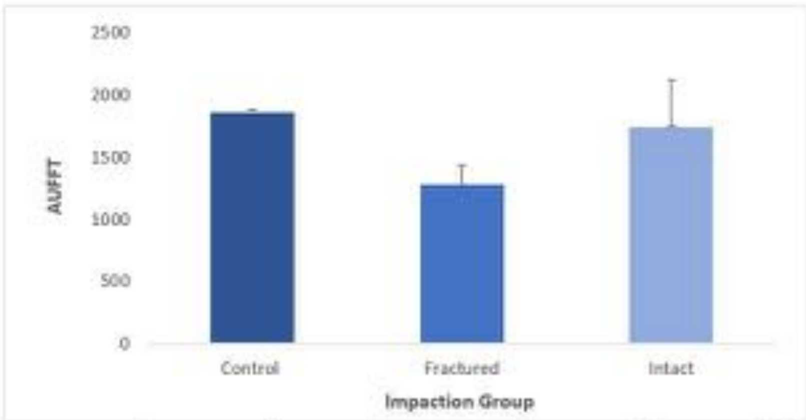

Fig3: Mean Area under FFT curve for powered impaction groups (n=90 sampled impactions) of control, intact, and fractured sawbones presented as bar chart and the data shown is that from an accelerometer positioned on powered impactor. Impactions 40-70 from each test were sampled to avoid transient behaviour giving n=30x3 per group

Figure 3

#5809

Mitigation of Surgical Outliers During Total Knee Arthroplasty With Navigation-Enhanced Instrumentation

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Computer-assisted orthopaedic surgery (CAOS) improves mechanical alignment and the accuracy of surgical cuts in the context of total knee arthroplasty. A simplified, CAOS enhanced instrumentation system was assessed to determine if the same effects could be achieved through the use of a less intrusive system. Two cohorts of surgeons (experienced and trainees) performed a series of total knee arthroplasty resections in knee models with and without navigation-enhanced instrumentation. The percentage of resections that deviated from the planned cut by more than 2°or 2mm (outliers) was determined by post-resection advanced imaging for six unique outcome metrics. Within each experience level, the use of the CAOS enhanced system significantly reduced the total percentage of outliers as compared to conventional instrumentation (Figure 1). The experienced users improved from 35% to 4% outliers overall ($p < .001$) and the trainees from 34% to 10% outliers ($p < .001$). Comparing across experience levels, the experienced surgeons performed significantly better in only a single resection metric with conventional instrumentation (Figure 2A), varus/valgus tibial alignment, with 8.3% outliers compared to the trainee's 63% outliers ($p = .004$). The use of CAOS enhanced instrumentation eliminated any differences between the two user groups for all measured resections (Figure 2B). Comparing CAOS enhanced to conventional instrumentation specifically between anatomical deformity types revealed that there is significant improvement ($p < .05$) with the use of enhanced instrumentation for all three deformity types (Figure 3). These results suggest that non-intrusive CAOS enhanced instrumentation is a viable alternative to conventional instrumentation with possible benefits. This trial also demonstrates that additional experience may not correlate to improved surgical accuracy, and outliers may be less a result of individual surgeon ability or specific anatomic deformities, and more so related to limitations of the instrumentation used or other yet unidentified factors.

Figure 1: Outlier rate comparison between conventional (grey) and navigation-enhanced (black) instrumentation by training level. * denotes $p < 0.001$.

Figure 2: (A) Outlier rate of cuts across six measurements using conventional instrumentation, comparing experienced users (grey) to trainees (black). (B) Outlier rate of cuts across six measurements using navigation-enhanced instrumentation, comparing experienced users (grey) to trainees (black). Absence of a measurement bar indicates an experimental outlier rate of 0%. * denotes $p < 0.05$.

Figure 3:Outlier rate by deformity type, across all training levels, for each instrument. Neutral (light grey), valgus (dark grey) and varus (black). * denotes $p < 0.05$.

Figures

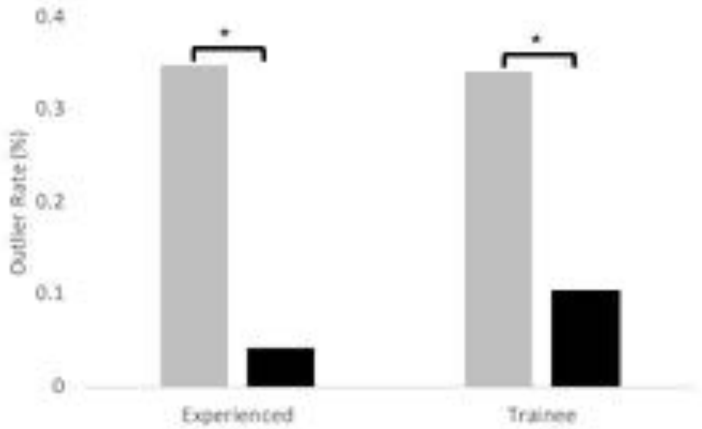

Figure 1

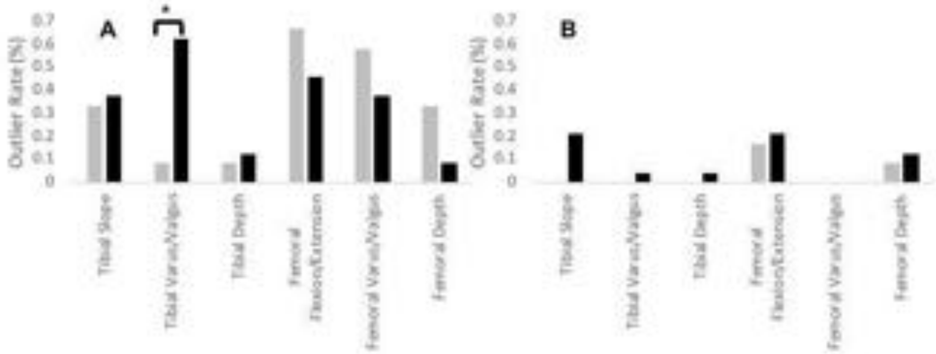

Figure 2

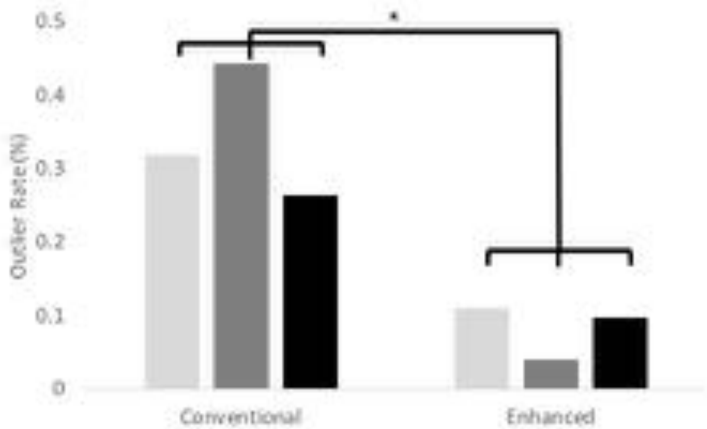

Figure 3

#6015

Accelerometer Measured Physical Activity Levels Before and After Total Hip Arthroplasty: A Cohort Study

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Introduction: Total hip arthroplasty is the most effective procedure for late stage hip arthritis. Higher physical activity levels following THA has multiple benefits for this population, including decreased morbidity and mortality. Measuring physical activity in patients can be difficult due to the unreliability of patient reported activity levels. To this end, accelerometers have grown in popularity due to their accurate measurement of exercise duration, frequency and exercise intensity. The purpose of this study is to assess pre-and-post operative levels of physical activity level amongst THA recipients utilizing prospectively collected accelerometer data.

Methods: The Osteoarthritis Initiative database was queried for all patients who underwent a THA after physical activity (PA) reading using accelerometer. Patients were divided into a progression sub-cohort, an incidence sub-cohort, and a control cohort. Inclusion criteria included patients who consented to wear an Actigraph GT1M uniaxial accelerometer and received a primary unilateral THA. This yielded a total of 44 patients **(Table 1)**.

Results: There was no significant difference in the average daily activity count for patients pre- and post-THA (p=0.72) **(Table 2)**. The difference in mean daily minutes of light activity was not significant (p=0.95), nor was the difference in mean daily minutes of moderate activity (p=0.23). Similarly, there was no significant difference found for the mean daily bout minutes of moderate-vigorous activity (p=0.47), the mean daily minutes of moderate-vigorous activity (p=0.27), the mean daily bout minutes of vigorous activity (p=0.83), and the mean daily minutes of vigorous activity (p=0.77).

Conclusion: While THA is effective at helping mitigate the symptoms of OA, most patients will maintain a post-operative activity level similar to their pre-operative state. There is no significant difference in PA levels before and after THA. Further studies should include larger sample sizes in a prospective study to investigate patient motivation and desire for increased activity, as this may play a role in PA achieved.

Figures

Table 1. Patient demographics.

Variable		P-value
Mean age at surgery (range) (yrs)	69.95 (54.81 to 82.74)	
Gender (% male)	43.8%	
Race (% of study population):		
White	44 (91.67%)	
Black or African-American	3 (6.25%)	
Asian	1 (2.27%)	
Other	0 (0%)	
Pre-THA BMI (S.D.) (kg/m²)	28.66 (±3.51)	0.477
Post-THA BMI (S.D.) (kg/m²)	28.03 (±3.61)	
Mean time until THA (days)	1836.05 (±21)	

Figure 1

Table 2. Results.

	Patients Pre-THA ± STDEV	Patients Post-THA ± STDEV	T-statistic	P-value
Mean average daily count	166,039.6 ± 91,615.6	177,578.6 ± 103,731.9	t = 0.3625	0.724
Mean daily minutes of light activity	243.8 ± 77.2378	251.4008 ± 78.9	t = 0.0572	0.956
Mean daily minutes of moderate activity	10.4 ± 11.8375	14.3050 ±14.3	t = 1.2829	0.226
Mean daily bout minutes of mod-vigorous activity	5.5 ± 7.7730	7.6667 (8.5)	t = 1.1744	0.470
Mean daily minutes of mod-vigorous activity	10.8 ± 11.9	14.7 ± 14.6	t = 1.1744	0.265
Mean daily bout minutes of vigorous activity	0.4 ± 1.7	0.47 ± 1.6	t = 0.2173	0.832
Mean daily minutes of vigorous activity	0.5 ± 1.39	0.42 ± 1.9	t = 0.2943	0.774
Patients who met DHHS guidelines (N)	1 (2.1%)	1 (2.1%)		0.753
Met DHHS guidelines for patients with arthritis (N)	1 (2.1%)	1 (2.1%)		

Figure 2

#5542

Effects of Variability With Impaction Strike Conditions on Vibroacoustic Signals for Bone Fracture

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Introduction

In Total Hip Arthroplasty (THA), proper bone preparation technique is fundamental to preventing intraoperative fracture. Anecdotally, surgeons suggest they can avoid fracture by listening for changes in the pitch of a mallet strike during broaching. Consequently, it is not surprising that researchers have explored vibroacoustic methods to prevent [1] and identify bone fractures [2, 3]. For instance, a shift in frequency of the acoustic signals during impaction has been correlated with initial stability [4, 5]. In-spite of these research-based successes, we are unaware of an intraoperative application for THA. We submit that idiosyncratic variability during impaction [6] may overwhelm analytical techniques developed in a controlled laboratory environment. The purpose of this test, therefore, was to evaluate the effect of several strike parameters on the vibro-acoustic response during impaction. Specifically, we hypothesized that the *angle, location*, and *force* of impaction would produce 'false-positives' in frequency regions that have been used to identify fracture [7].

Methods

A Sawbones femur (SKU1121, Medium) was prepared and broached using standard surgical technique for the Summit hip system (DePuy Synthes) progressing from size 0 to 4. The size 4 broach was firmly seated and impacted ten times (n=10) for each of the prescribed conditions (Table 1) while securely holding the femur by hand. Vibroacoustic data from an accelerometer attached distally on the femur and a directional microphone located within 1 metre (Figure 1) were acquired at a sampling rate of 40kHz and postprocessed using LabView. Spectrograms were generated for qualitative comparisons, while fast fourier transform (FFT) with normalised amplitudes for each strike facilitated quantitative analysis of the area under the FFT curve (AU-FFT). Strike conditions were monitored to ensure the groups were consistent and distinct (Table 1).

Results

There were statistically significant differences in strike conditions for *angle* (30° vs 60°), *location* (centre vs medial and lateral) and *force* (medium vs low and high) (Figure 2). Data describing the strike conditions revealed consistent and distinct groups (data not shown).

Discussion and Conclusion

We have demonstrated that variability in striking does influence the vibroacoustic signal during impaction; however, contrary to our hypothesis, this variability does not overwhelm the ability to distinguish between fractured and intact impaction signals. Consequently, the AU-FFT comparator could be a robust and useful metric. Future work could evaluate this technique under more diverse conditions with multiple samples of varying anatomies, densities, and degrees of fracture. The above methods and paradigms could further be investigated to discern when a broach is properly seated and thereby avoid the risk of fracture altogether.

References

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Figures

Table 1: Experimental groups and strike conditions tested. The monitoring methods used to verify applied conditions for each strike are also indicated.

	Strike Conditions		
Experimental Group	**Angle**	**Location**	**Force**
Effect of Angle	0°, 30°, 60°	Centre	Mid
Effect of Location	0°	Lateral, Medial, Centre	Mid
Effect of Force	0°	Centre	High, Mid, Low
Assessment Method	*Gyroscope (IMU)*	*Colour transfer*	*Acoustic amplitude*

Figure 1

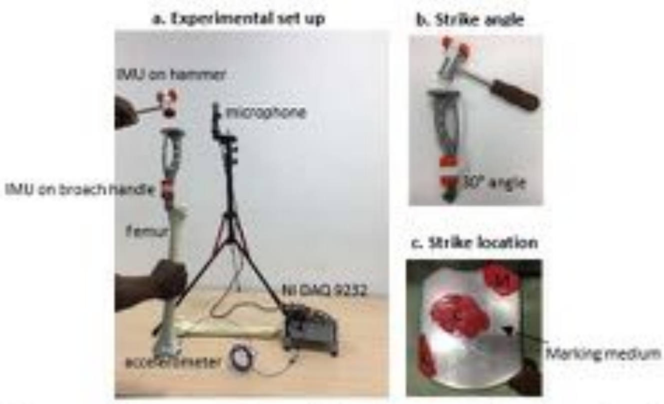

Figure 1: Illustration of a.) Experimental set up b.) strike contact angle relative to long (vertical) axis of broach handle depicting target strike angles of 30° measured with an inertial measurement unit (IMU), c.) transferrable marking medium used to identify impaction strike location. An acoustic amplitude from an air microphone was used to indicate force magnitude

Figure 2

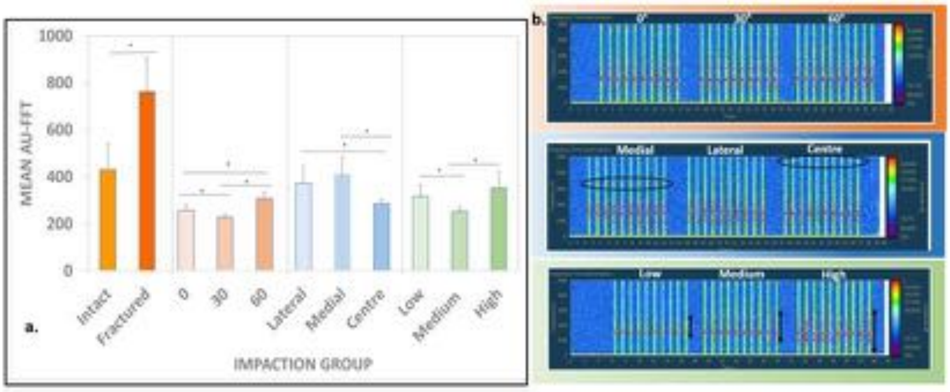

Figure 2: a) Mean area under the FFT (AU-FFT) curve for intact and fractured bone groups [7], and the different strike conditions; b) Frequency-time-amplitude spectrograms comparing strike *angle* (top), *force* (middle), and location (bottom). *Represent statistically significant difference (p<0.05) between groups

Figure 3

#5495

Soft Tissue Balance in ACL Deficient Osteoarthritis Knee at Total Knee Arthroplasty

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INTRODUCION:

Appropriate soft tissue balance is an important factor for postoperative function and long survival of total knee arthroplasty(TKA). Soft tissue balance is affected by ligament release, osteophyte removal, order of soft tissue release, cutting angle of tibial surface and rotational alignment of femoral components.The purpose of this study is to know the characteristics of soft tissue balance in ACL deficient osteoarthritis(OA) knee and warning points during procedures for TKA.

METHODS:

We evaluated 139 knees, underwent TKA (NexGen LPS-Flex, fixed surface, Zimmer) by one surgeon (S.A.) for OA. All procedures were performed through a medial parapatellar approach. There were 49 ACL deficient knees. A balanced gap technique was used in 26 ACL deficient knees, and anatomical measured technique based on pre-operative CT was used in 23 ACL deficient knees.To compare flexion-extension gaps and medial-lateral balance during operations between the two techniques, we measured each using an original two paddles tensor (figure 1) at 20lb, 30lb and 40lb, for each knee at a 0 degree extension and 90 degree flexion. We measured bone gaps after removal of all osteophytes and cutting of the tibial surface, then we measured component gaps after insertion of femoral components. Statistical analysis was performed by t-test with significant difference defined as $P<0.05$.

RESULTS:

(1) There were 90 ACL remaining knees and 49 deficient knees. Each group's preoperative FTA was 174±2.9 degrees, 173±3.2 degrees, preoperative range of motion(ROM) was extension -3.3±5.5 degrees, -2.3±4.9 degrees, flexion 119.4±12.5 degrees, 117.7±12.0 degrees, post-operative β angle was, 88.1±2.5 degrees, 88.5±2.5 degrees. There were no significant differences between two groups. Comparing bone gap, medial gap and lateral-medial gap at a 30lb flexion were significantly different($P<0.05$). (table1)

(2) Comparing component gaps using modified gap techniques (group G) and anatomical techniques (group A) in ACL deficient knees, extension of medial and lateral gaps at 30lb and 40 lb in anatomical technique was bigger. The lateral-medial gap at 30lb was bigger in anatomical techniques. ($P<0.05$) (table 2)

DISCUSSION:

The present results showed that ACL deficient OA knee were looser at medial side compared with ACL remaining OA knees. It indicates that we performed medial rerelease carefully in ACL deficient TKA. When we used gap techniques, medial loosening caused malposition of femoral components, and when we used anatomical techniques, extension gap was bigger than using gap techniques because generally smaller femoral components were chosen.

It is reported that lateral gaps are bigger in severe varus deformity OA than slightly deformed OA knees. It is also reported the correlation of lateral thrust with ACL deficiency and the progression OA, and when OA is developed, lateral side becomes loose. Our study indicated that ACL deficient OA knee progress rotational instability, in addition to antero-posterior instability, and subsequent medial loosening at knee. Furthermore, the present study shows that traumatic ligament injury caused OA knees include medial loosening knees.

Figures

Figure 1: Our original tensor.

Figure 1

	extension 0° (30lb)		
	medial	lateral	lateral-medial
ACL (+) (mm)	17.4±3.8	17.7±3.8	0.0±1.9
ACL (−) (mm)	18.5±3.7	18.7±4.2	0.2±1.6
	Flexion 90° (30lb)		
	medial	lateral	lateral-medial
ACL (+) (mm)	12.4±2.3	16.4±3.6	4.0±2.9
ACL (−) (mm)	13.3±2.5*	16.5±3.0	3.0±2.1 *

Table 1: Bone gap. Medial gap was bigger in ACL deficient OA knees (*P<0.05).

Figure 2

	20lb	30lb	40lb
medial	Extension 0°		
G group(mm)	9.6±0.9	10.5±1.3	11.8±2.0
A group(mm)	10.0±1.5	11.7±2.3*	13.1±2.2*
	Flexion 90°		
G group(mm)	12.7±2.5	15.2±3.0	17.0±4.0
A group(mm)	12.6±2.7	15.0±3.1	17.0±3.2
latera	Extension 0°		
G group(mm)	11.4±1.7	12.5±2.2	13.9±3.1
A group(mm)	12.0±1.8	14.3±2.6*	16.2±2.8*
	Flexion 90°		
G group(mm)	12.1±2.5	15.3±3.5	18.5±3.5
A group(mm)	13.0±2.7	17.2±3.6	19.6±3.7
lateral-medial	Extension 0°		
G group(mm)	1.7±1.4	1.9±1.6	2.0±1.8
A group(mm)	1.7±1.8	1.9±2.6	3.0±2.7*
	Flexion 90°		
G group(mm)	-0.5±3.3	0.8±3.2	1.5±2.7
A group(mm)	0.4±2.4	2.1±2.8*	2.5±2.5

Table 2: Component gap. Extension gaps in group A was bigger than group G. Discrepancy of lateral and medial gaps in group A was bigger than group G at flexion 30lb.(P<0.05)

Figure 3

#5717

Evaluation of Soft Tissue Balance Using a Pneumatic Tensor Device in Total Knee Arthroplasty

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Aims: Soft tissue balancing is one of the most important factors for success of total knee arthroplasty (TKA). We developed a new tensioning device using pneumatic pressure which can use continuously during knee motion. The purpose of this study was to analyze the accuracy of the pneumatic tensor in measurement of joint gap.

Methods: The subjects were 38 osteoarthritic knees with varus deformity that underwent primary posterior-stabilized TKA using the modified gap technique. Extension and flexion gaps were measured with two different type tensor devices: seesaw type – N-tensor (Teijin-Nakashima medical Co., Ltd, Okayama, Japan) and the pneumatic tensor using Nitrogen (N_2) gas. Constant distraction force (40 lbs) can be exerted in each femorotibial compartment. After the trial implantation of the femoral component, the joint gap (implant gap) was measured at 0º, 30º, 60º, 90º, 120º of flexion using the pneumatic tensor.

Results: The mean extension and flexion gap widths were 22.8 and 13.6mm for N-tensor and 23.6 and 16.5mm for the pneumatic tensor. The mean extension and flexion gap tilts were 3.7º and 4.5º for N-tensor and 2.4º and 5.5º for the pneumatic tensor. There were significant linear correlations between N-tensor and the pneumatic tensor for extension gap (width: r=0.62; P<0.001, tilt: r=0.74; P<0.001) and flexion gap (width: r=0.74; P<0.001, tilt: r=0.65; P<0.001). The gap widths after implantation were 15.5, 18.2, 18.7, 18.4 and 17.8mm at 0°, 30°, 60°, 90° and 120°, respectively. The implant gap width significantly increased from 0° to 30° of flexion (P < 0.001).

Conclusions: The new pneumatic tensor and the standard seesaw type tensor showed similar results in soft tissue balancing. The results of this study demonstrate that the pneumatic tensioning device can enable us to properly evaluate the soft tissue balance throughout any range of motion during TKA with acceptable reproducibility.

#5883

Comparison of 3-Years Postoperative Knee Stability After PS-TKA Between Medial Preserving Gap Technique and Measured Resection Technique

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Introduction

Modified gap technique has been reported to be beneficial for the intraoperative soft tissue balancing in posterior-stabilized (PS) -TKA. We have found intraoperative ligament balance changed depending on joint distraction force, which might be controlled according to surgeons' fells.

We have developed a new surgical concept named as "medial preserving gap technique (MPGT)" to preserve medial knee stability and provide quantitative surgical technique according to soft tissue balance measurement using a tensor device.

The purpose of this study was to compare 3-years postoperative knee stability after PS-TKA in varus type osteoarthritic (OA) knees between MPGT and measured resection technique (MRT).

Material & Method

The subjects were 94 patients underwent primary unilateral PS-TKA for varus type OA knees. The surgical technique was MPGT in 47 patients and MRT in 47 patients.

An originally developed off-set type tensor device was used to evaluate intraoperative soft tissue balance. In MPGT, medial release was limited until the spacer block corresponding to the bone thickness from lateral tibial plateau could be easily inserted. Femoral component size and external rotation angle were adjusted depending on the differences of center gaps and varus angles between extension and flexion before posterior femoral condylar osteotomy (Fig. 1).

The knee stabilities at extension and flexion were assessed by stress radiographies at 1 and 3 years after TKA; varus-valgus stress test at extension and stress epicondylar view at flexion. We measured medial and lateral joint openings (MJO, LJO) at both knee extension and flexion.

MJOs and LJOs at 2 time periods were compared in each group using paired t-test. Each joint opening distance was compared between 2 groups using unpaired t-test. The significance level was set as $P < 0.05$.

Results

The mean extension MJOs at 1 and 3 years after TKA were 2.4, 2.6mm in MPGT and 3.2, 3.1mm in MRT respectively. The mean extension LJOs were 3.5, 3.5mm in MPGT and 4.6, 4.5mm in MRT. The mean flexion MJOs were 0.95, 0.77mm in MPGT and 1.5, 1.2mm in MRT, and the mean flexion LJOs were 2.2, 2.1mm in MPGT and 3.0, 2.7mm in MRT.

MJOs were significantly smaller than LJOs in each group at 2 time periods. MJOs at extension and flexion, and LJOs at extension were significantly smaller in MPGT than MRT at 2 time periods (Fig. 2, 3).

Discussion

MPGT was useful to preserve the higher medial knee stability than the lateral as well as MRT, and beneficial to enhance postoperative knee stabilities as long as 3-years after PS-TKA in varus OA knees. MPGT is also objective gap technique depending on quantitative tensor measurements not relying on surgeons' subjective fells, and advantageous to preserve medial knee stabilities at extension and flexion which had been reported to be essential for postoperative clinical results. We believed MPGT would be an objective and safer gap technique to enhance clinical outcomes.

Figures

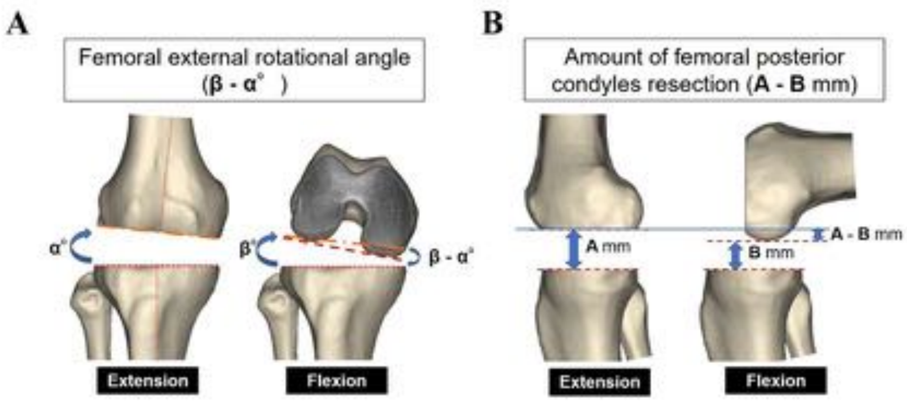

Fig. 1: Schematic explanations for "medial preserving gap technique"
Measurement of varus ligament balance (A) and joint center gap (B) were performed between femoral and tibial osteotomized surfaces at extension, and between the femoral posterior condyle and tibial osteotomized surfaces at flexion.
A: The difference in varus ligament balance at extension and flexion (β-α°) was used for determining the femoral external rotation angle.
B: The difference in joint center gap at extension and flexion (A-B mm) was used for determining the amount of femoral posterior condyles resection.

Figure 1

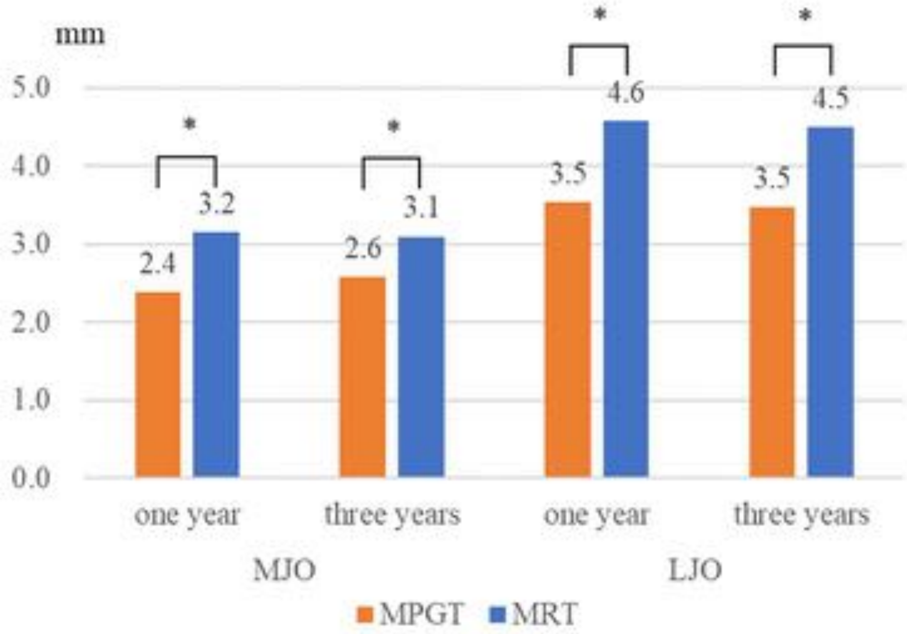

Fig. 2: Medial and lateral joint opening at extension (*: p<0.05)

Figure 2

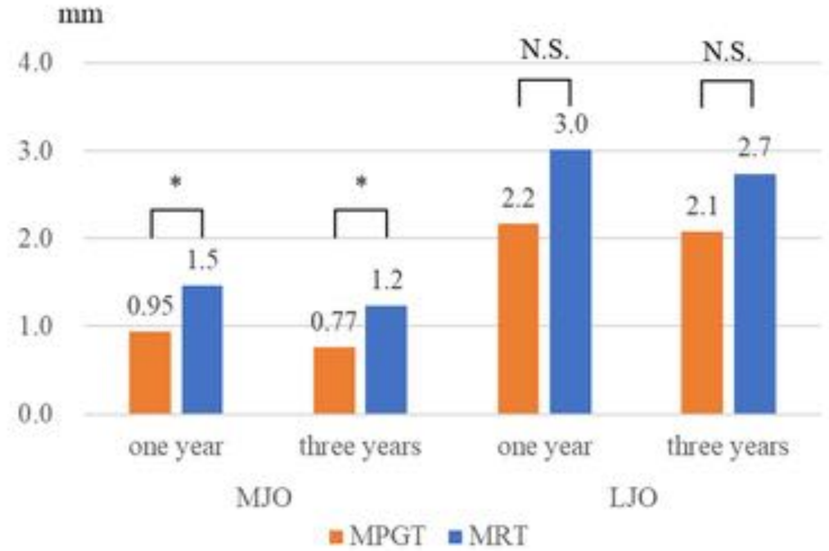

Fig. 3: Medial and lateral joint opening at flexion (*: p<0.05, N.S.: not significant)

Figure 3

#5566

Coronal Laxity in Total Knee Arthroplasty: an Intraoperative Measurement

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Introduction

Soft-tissue management is critical for total knee arthroplasty (TKA). Experimental knee laxity measurements using calibrated force and special fixtures are not intraoperatively practical. Therefore, the results may differ from the knee laxity observed in the operating room. This study quantified coronal knee laxity before and after TKA implantation, measured intraoperatively using a computer-assisted orthopaedic surgery (CAOS) system.

Materials and Methods

Seventy-six consecutive cruciate-retaining (CR) TKAs were performed by the surgeon author. A modified gap balancing technique was applied to all cases with measured resection in extension, followed by gap balancing in flexion, aiming for symmetrical flexion-extension and mediolateral gaps.

Manual varus/valgus stress tests were performed across the range of motion (ROM) with patella reduced under two knee conditions: 1) arthritic: tested just after medial parapatellar exposure and attachment of the CAOS trackers; and 2) TKA: tested with trial implantation. Coronal laxity at flexion angles of 0°, 40°, and 90° was recorded by the CAOS system (Fig. 1) and compared (paired-t test) across test conditions. The specific measures investigated were: varus laxity, valgus laxity, size of the laxity envelope, and the center of the laxity envelope at full extension. Statistical significance was defined as $p < 0.05$.

Results

During mid-flexion (40°), the arthritic knees exhibited significantly elevated varus and valgus laxity (p values < 0.004) and larger laxity envelope (p values = 0.000), compared to 0° and 90° of flexion (Fig. 2). At 90° flexion, the laxity of the arthritic knees was asymmetric, with the center of the envelope deviated on average 3.2° from the neutral center.

Clear differences in laxity were observed between arthritic and trial implanted knees (Table.1, Fig. 2). After trial implantation, the elevated laxity during mid-flexion was no longer observed. The varus and valgus laxity angles were generally consistent across the flexion range, except for a slightly (<2°) more varus laxity in flexion (40° and 90°) compared to extension (0°). With trial implantation, both size and asymmetry of the laxity envelope significantly decreased from arthritic knee. At full extension, all the implanted knees had varus valgus and valgus laxity of no more than 3° and 5°, respectively, and the valgus laxity was slightly (1.4°) higher than varus laxity ($p = 0.001$).

Discussion

This study provided insight into coronal knee laxity during TKA. In the arthritic knees, the elevated mid-flexion laxity may indicate reduced rotational support provided by passive joint structures. TKA surgery significantly reduced varus/valgus laxity across the flexion range and removed the pattern of mid-flexion elevation, reflecting stabilization of the knee joint by the surgical intervention. The study may be limited by the single surgeon data and manual stress tests. However, it represented the clinically observed laxity during TKA surgeries. The implanted knees in this study exhibited the same trend as previous reports on normal knees, which showed a consistent increase in varus/valgus laxity envelope with increased knee flexion, and higher valgus laxity than varus laxity. Studying intraoperatively measured knee laxity by CAOS technology may help enhance knowledge of soft-tissue balance under clinical setting

Figures

	Flexion (°)		
	0	40	90
Varus Laxity (°)			
Arthritic Knee	2.7 ± 4.6	5.5 ± 5.1	4.2 ± 5.4
TKA	0.0 ± 1.4	1.6 ± 3.3	1.7 ± 4.3
P	0.000	0.000	0.000
Valgus Laxity (°)			
Arthritic Knee	-2.0 ± 4.3	-3.2 ± 5.8	-2.4 ± 5.3
TKA	-1.1 ± 1.6	-1.3 ± 3.4	-1.5 ± 4.3
P	0.037	0.001	0.024
Laxity Envelope (°)			
Arthritic Knee	5.3 ± 3.9	8.4 ± 4.4	6.6 ± 4.1
TKA	1.6 ± 1.2	3.2 ± 2.6	3.3 ± 2.7
P	0.000	0.000	0.000

Table 1. Summary of measured coronal laxity.

Figure 1

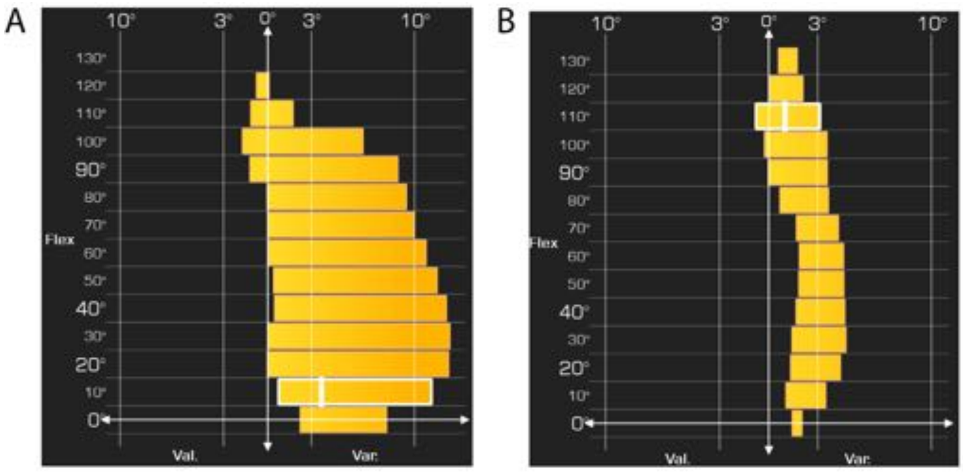

Figure 1. A representative surgical record demonstrating intraoperative coronal laxity test results for A) intact OA condition and B) after TKA trial implantation.

Figure 2

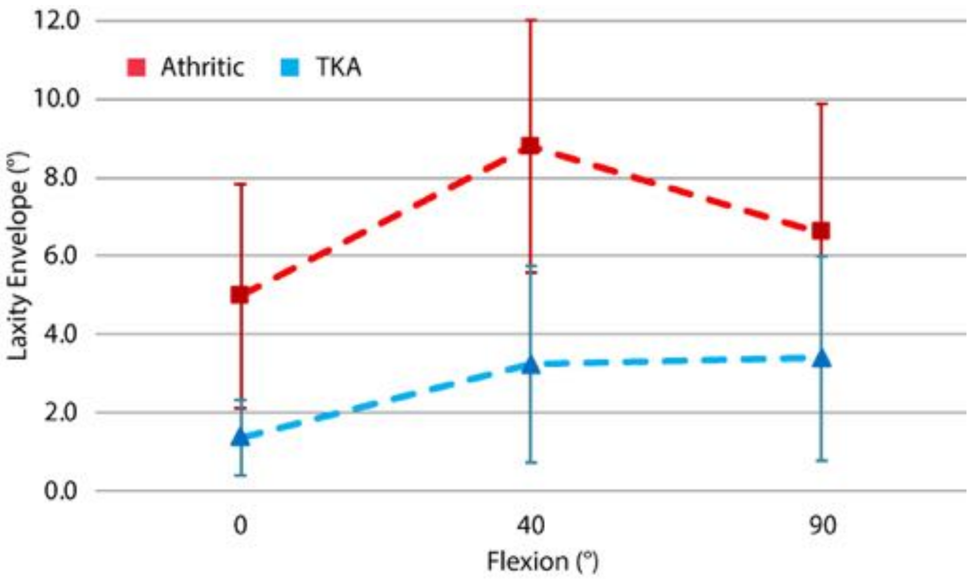

Figure 2. Comparison of the size of coronal laxity envelopebetween flexion angles and the two test conditions.

Figure 3

#5584

Patients Height and Preoperative Alignment Affect Soft Tissue Balancing in Total Knee Arthroplasty: A Cross-Sectional Retrospective Study on Continuous Determination of Distraction Force

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Background

ã€€Although the distraction force for the intraoperative extension gap in total knee arthroplasty (TKA) has been defined in accordance with the manufacturer's recommendation beforehand, the problem seems to be the lack of consideration of patient characteristics. Therefore, we aimed to clarify whether preoperative factors affected soft tissue balancing by using a novel method with equipment that enables continuous quantification of distraction force.

Methods

ã€€A total of 35 knees in 33 patients treated with cruciate-retaining TKAs (Scorpio NRG; Stryker Howmedica Osteonics, Mahwah, NJ, USA) were retrospectively enrolled in this analysis with a mean age of 74 (range, 58-86) years at the time of surgery. All TKAs were performed by the senior author, who used the measured resection technique with a tourniquet under general anesthesia and regional analgesia. They are measured the extension gap three times after femoral trial placement with reduced patellofemoral joint by customized equipment (DynAccurate; Stryker) (Fig.1). Two observers examined the intraclass correlation coefficient (ICC [2, 1]) to investigate the reliability of this equipment by conducting in vitro and in vivo studies. The coefficient of determination was assessed from the simple regression line of the extension gap between the distraction force of 0 and 40 lbf. On the basis of this regression line, we calculated the distraction force required for the extension gap of the selected insert thickness (Req-DF), and the extension gap of 30 lbf (f-30) and 40 lbf (f-40). Linear regression analysis was used to identify the relationships between the preoperative factors and soft tissue measurement (Req-DF, f-30 and f-40). A p value of < 0.05 was considered significant.

Results

ã€€ICCs (2, 1) were 0.99 and 0.97 in the in vitro and in vivo studies, respectively. The median (interquartile range;25th to 75th percentiles) was 0.96 (0.85-0.99) for the coefficient of determination between the extension gap and the distraction force,16.5 lbf (9.8-32.9 lbf) for Req-DF, 10.4 mm (8.3- 16.1 mm) for f-30, and 12.0 mm (9.0-19.1 mm) for f-40. Req-DF exhibited a correlation with neither patient's height ($p = 0.07$) nor preoperative % mechanical axis ($p = 0.23$). However, f-30 and f-40 correlated with the height ($r = -0.38$, $p = 0.02$; and $r = -0.36$, $p = 0.03$, respectively) and the percentage ($r = -0.33$, $p = 0.04$; and $r = -0.35$, $p = 0.03$, respectively) (Table.1).

Conclusions

ã€€The above-mentioned evaluation (Req-DF) using DynAccurate gave high agreement and had less influence on patient's height and *preoperative alignment* than the conventional tensor, with respect to extension gap. This cross-sectional study on

continuous determination of distraction force provides useful information for a more accurate and extensive analysis of soft tissue balancing.

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Figures

Fig.1 DynAccurate. Digital balancer (tensor), which can measure intraoperative gaps, angles, and distraction forces simultaneously, manufactured by Japanese vendors. This tensor firmly fixed the osteotomized tibia by pins and additional pins on the platform plate.

Table.1 Correlation between the preoperative factors and soft tissue measurements

	f-30	f-40	Req-DF
Age at surgery (years)	n.s.	n.s.	n.s.
Height (cm)	–*	–*	n.s.
Weight (kg)	n.s.	n.s.	n.s.
Body Mass Index	n.s.	n.s.	n.s.
Preoperative knee extension (°)	n.s.	n.s.	n.s.
Preoperative knee flexion (°)	n.s.	n.s.	n.s.
% Mechanical Axis (%)	–*	–*	n.s.

Abbreviations: n.s., not significant; *, $p < 0.05$

Negative values indicate negative correlation.

Figure 1

Less Compressive Force on the Posterolateral Compartment Can Correlate With More Flexion Angle Following Cruciate-Retaining TKA: A Retrospective Observational Study.

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Although the pre- or intraoperative flexion angle in TKA has been commonly considered as a predictor of the postoperative flexion angle, patients with well flexion intraoperatively cannot necessarily obtain deep flexion angle postoperatively. The reason why inconsistencies remains has been unsolved. The intraoperative compressive force between femoral and tibial components has the advantage of the sequential changes during knee motion. However, the relationship between the compressive force and the postoperative ROM has not yet been clarified. We aimed to evaluate the intraoperative femorotibial compressive force during passive knee motion, and determine the relationship between the compressive force and the postoperative flexion angle.

A total of 11 knees in 10 patients who underwent primary cruciate-retaining (CR) TKA (The FINE Total Knee System; Teijin Nakashima Medical Co., Ltd., Okayama, Japan) for osteoarthritis were studied retrospectively, with a mean age of 76 years via a measured resection technique. We developed a customized measurement device mimicking the tibial component with this platform of six load sensors arranged in two rows (medial and lateral) by three tandem sets (anterior, center and posterior): anteromedial (AM), anterolateral (AL); centromedial (CM), centrolateral (CL); and posteromedial (PM), posterolateral compartment (PL) (Fig. 1). At the step of the implant trial, this device was placed on the tibia with compressive force recorded three times, while the knee was subsequently taken from 0° to full flexion manually in 15 seconds with the flexion angle of the knee recorded simultaneously by using an electric goniometer (Fig. 2). Eligibility were evaluated for ROM using a long-armed goniometer preoperatively and at 6 months postoperatively. A p value of < 0.05 was considered significant.

The mean compressive force at AM, AL, CM, CL, PM and PL was 0.7, 0.5, 1.3, 1.2, 3.4 and 2.6 kgf, with the peak force of 4.2, 2.5, 4.1, 2.5, 7.3 and 4.7 kgf, respectively. The mean pre- and postoperative extension and flexion angles were -11° and -6°; and 115° and 113°, respectively. There were no significant correlations between the mean force in any region of interest (AM to PL) and the postoperative flexion angle. The peak force in PM showed little correlation with the postoperative flexion angle ($r = -0.17$, $p = 0.54$), however, that in PL was strongly negatively correlated with the postoperative flexion ($r = -0.86$, $p < 0.01$).

The current results suggest the presence of less force on the lateral side in flexion. We speculate that lower compressive force at the lateral side is essential for deep flexion as it has been reported that the lateral structure has more laxity than the medial side during flexion in healthy knees. Measurement between the femoral and tibial compressive force can contribute an achievement of more flexion angle following CR-TKA.

Figures

Figure 1

Figure 2

Sensor Assisted Balancing: Does a Surgeon Need the Extra Sense?

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Introduction & Aims – The intra-operative assessment of soft-tissue balance during total knee arthroplasty (TKA) has historically been made by surgeons' subjective feel. While there have been attempts to standardize ligament balancing by using gap balancing or measured resection techniques, no quantitative, gold-standard technique has yet been established. In this study, the subjective feel of experienced surgeons was compared to objective, quantitative feedback using an intra-operative load sensor. It was thereby hypothesized that surgeons' feel poorly predicts the state of soft tissue balance in TKA.

Method – A cohort of 170 patients were analyzed in this multi-center study. During the final trialing of TKA, surgeons assessed the stability of the knee. By their experienced feel, the knees were subjectively categorized as either tight, balanced or loose medially or laterally in both extension and flexion. Subsequently, an instrumented tibial trial component was inserted that captured the medial and lateral tibiofemoral loads. This allowed the quantitative assessment of the state of balance through the range of motion. An absolute mediolateral load differential of less than 15 lbf was thereby characterized as quantitatively balanced, as previously reported. Knees with a medial load that exceeds the lateral load by more than 15lbf were evaluated as medial tight. The opposite applied for the lateral compartment. Subsequently, we analyzed the mismatch between quantitative sensor balance and the surgeon-defined assessment of balance.

Results – Of the knees that were balanced according to the surgeons' qualitative assessment, approximately half were actually quantitatively balanced (46% in extension and 57% in flexion). On the contrary, those knees that were judged as unbalanced by the surgeons appeared quantitatively balanced in 58% of the cases (both in extension and flexion). An even more pronounced discrepancy was observed for the knees that were judged medially tight by the surgeon: only 27% and 29% were quantitatively tight on the medial side in extension and flexion, respectively. The same observation was made for laterally tight knees, with a correspondence between the qualitative and quantitative assessment in 31% and 39% of cases only (extension and flexion, respectively).

Conclusions – The surgeon poorly feels the quantitative balance of the knee. In approximately half of the cases, surgeons incorrectly perceived that the knee was balanced while quantitative data indicated an unbalanced state. Quantitative sensor data thus provides the surgeon with an additional sense. Clinical follow-up of the balanced and unbalanced subjects is ongoing to determine whether balanced knees lead to better outcomes.

Using a Novel Posterior Referenced Gap Sizer Improves Soft Tissue Balance Even After PCL Resection, Kinematic Analyses During Computer Assisted Total Knee Arthroplasty

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Introduction

Posterior reference point of conventional sizer is in the middle of medial and lateral condyle of posterior femur in total knee arthroplasty (TKA). This method may lead to possibility that lateral condyle of posterior femur is cut thinner, and medial condyle is cut thicker than aimed thickness. Medial flexion gap might be loosened and this possibility might cause instability of knee joint.

Based on these backgrounds, a new posterior reference sizer named “Advanced Gap Sizer(AGS)” is produced in Japan (Figure.1). In this new sizer, Optional amount of bony cut can be set with medial or lateral fulcrum, that leads to easy to control gap of femoro-tibial joint in even measured resection method.

It is hypothesized that with this new posterior reference sizer, the bone of medial condyle of posterior femur can be cut with same thickness as that of implant, and this technique might be able to avoid from loosening of medial flexion gap.

The purpose of this study is an investigation of in vivo kinematics of femoro-tibial joint with use of AGS using computer assisted navigation system and tensor device intra-operatively in TKA.

Materials and Methods

Eighty-five consecutive patients who had knees of osteoarthritis with varus deformity were investigated in this study. All TKAs (Triathlon, Stryker) were performed using computer assisted navigation system. We divided into two groups, one group using conventional sizer (Conventional group), another group using advanced gap sizer (AGS group) for cutting posterior condyles of femur. During surgery, using a tensor device, after bony cut of femur and tibia and insertion of femoral component trial, joint gaps were assessed in 0, 30, 60, 90 and 120 degrees in flexion before and after posterior cruciate ligament (PCL) respectively. The kinematic parameters of the soft-tissue balance, and amount of coronal and sagittal relative movement between femur and tibia were also recorded throughout the range of motion in the navigation system.

Results

Evaluation of soft tissue balance with tensor device revealed that AGS group was able to reduce spreading of flexion gaps significantly compared with conventional group before PCL resection (Figure.2).

Furthermore, even after PCL resection, soft tissue balances were able to maintain tight adaptively through range of motion in AGS group compared with in conventional group (Figure.3).

Discussion

One of the most important principles for ligament balancing in TKA for varus knees is involved that the medial flexion gap should be equal to the medial extension gap (or 1-2 mm larger), because this provides close to normal stability and a larger medial flexion gap would worsen knee function. In TKA with Measured resection method, thickness of bone cut in medial condyle of femur should be same as that of implant, in both distal and posterior condyle in theory.

In this study, with use of this new posterior referenced sizer, there is high possibility that it might be easy to acquire the optimal gap control in TKA.

Figures

Figure. 1

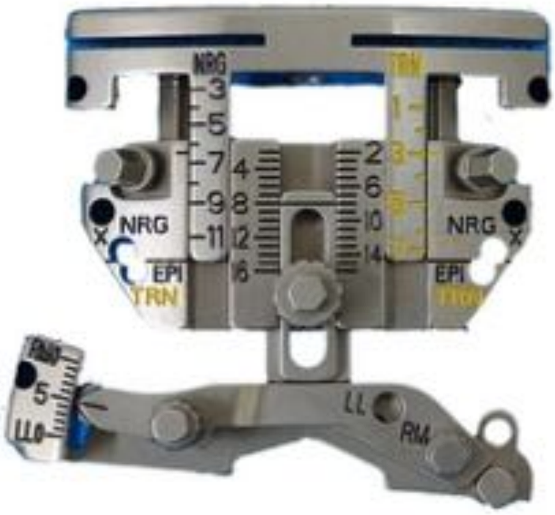

Figure 1

Figure. 2

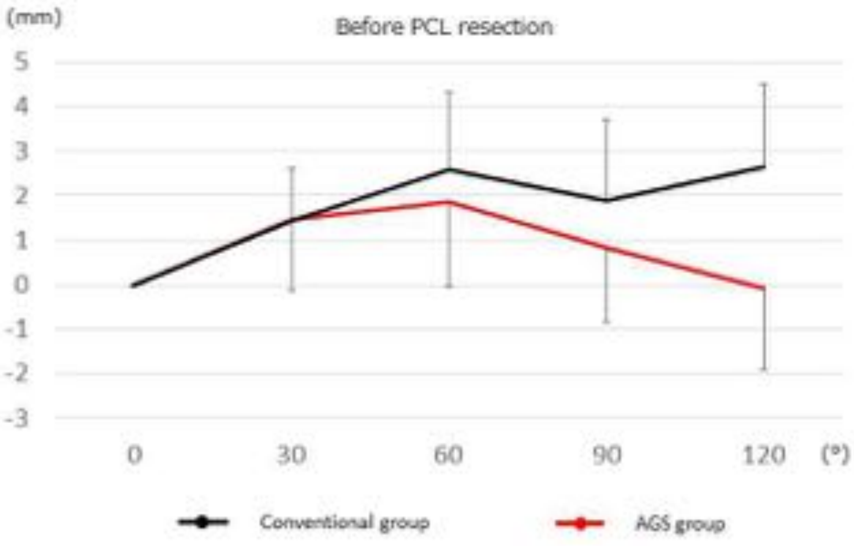

Figure. 3

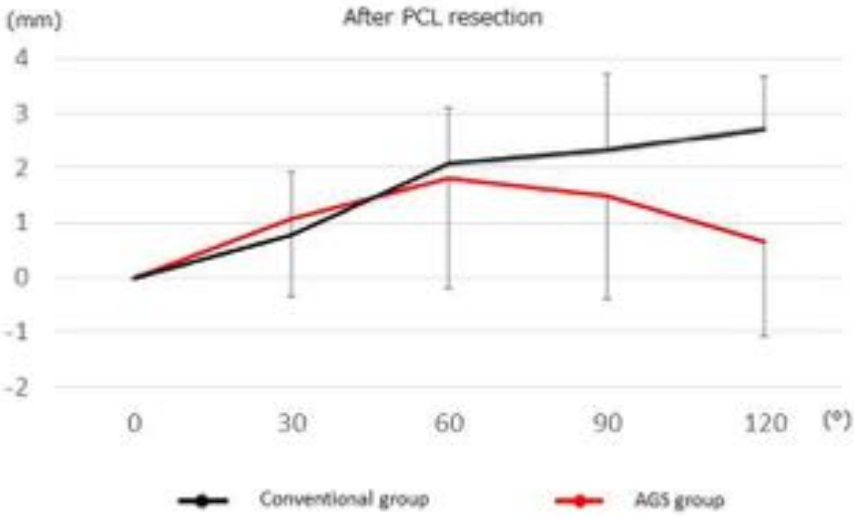

Figure 2

#5621

Dynamic Sensor-Balanced Knee Arthroplasty: Can the Sensor Train the Surgeon?

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Background: Dynamic tibial tray sensors are playing an increasing role in coronal-plane TKA balancing. Sensor-balance is proposed to lead to improved patient satisfaction and outcomes compared with sensor-unbalanced TKA, and traditional manual-balanced TKA performed without the sensor. What is not known is whether there is a learning curve with this technology, and whether sensor-use can improve manual TKA balance skills once the sensor is taken away, and consequently “train” the surgeon.

Methods: We conducted a single-surgeon prospective study on 104 consecutive TKAs performed at our institution. In Nonblinded Phase I (n=49), sensor-directed releases were performed during trialing and final intercompartmental pressures were recorded. In Blinded Phase II (n=55), manual-balanced TKA was performed and final sensor readings were recorded by a blinded observer after final cementation. We used cumulative summation (CUSUM) analysis and sequential probability ratio testing to analyze the surgeon learning curve in both phases.

Results: In Nonblinded Phase I, sensor-balance mastery was attained most easily at 10°, followed by 90°, and most difficult to attain at 45° of flexion. In Blinded Phase II, manual-balance was lost most quickly at 45°, followed by 90°, and preserved for longest at 10°of flexion. The number of cases in the steady state periods (early phase periods where there is a mix of sensor-balance and sensor-imbalance) for both phases is similar.

Conclusions: A surgeon who consistently uses the dynamic sensor demonstrates a learning curve with its use, and an “attrition” curve once it is removed. Consistent sensor-balance can only be guaranteed with constant sensor use.

#5643

Can the Subvastus Approach for TKA Help in Achieving High Flexion in Highflex Knees ? Results of 242 Knees at 4 Years

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Objective: To evaluate the clinical and functional outcomes obtained by combination of high-flexion Freedom® Total Knee System (TKS) and mini-subvastus approach in total knee replacement patients.

Method: This is a retrospective, observational, real world study conducted at Mumbai in India from 2011 to 2016. All patients who were above the age of 18 and operated for total knee replacement (TKR) with mini-subvastus approach using Freedom (Maxx Medical) by the senior author were included. The Implant survivorship was the survey endpoint; primary endpoint was range of motion (ROM); and secondary endpoints were AKSS (American Knee Society Score) and WOMAC (Western Ontario and McMaster Universities Osteoarthritis) scores collected pre- and post-operatively.

Results: 184 patients with 242 knees (126 unilateral and 58 bilateral) were operated with high-flexion TKS. Average age of patients was 70 ± 6.2 years. The mean ROM increased from 99.4°±10.44° (50°-120°) preoperatively to 116.78°±8.18° (88°-140°) postoperatively ($p<0.001$). Clinical and functional AKSS scores improved from 60.83±5.12 to 91.16±2.19 ($p<0.001$) and 65.35±3.52 to 99.13±4.61 ($p<0.001$) respectively. There average WOMAC pain scores improved from 12.12±1.72 to 0.066±0.37 (<0.0001). Moreover, post-operative WOMAC stiffness and function scores depicted significant improvement from 4.43±0.97 to 0.03±0.26 ($p<0.0001$) and 0.03±0.26 to 0.18±1.21 ($p<0.0001$) respectively at a mean follow-up of 3.71 ± 0.98 years. Implant survivorship was 100%.

Conclusion: High-flexion Freedom® TKS demonstrated a satisfactory clinical and functional improvements including high flexion when operated by the mini-subvastus approach at a mean FU of 4 years.

#5863

Mid-Term Results of TKA by the Hybrid Navigation Technique (Combination of Navigation and Gap Technique)

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INTRODUCTION
In gap balancing technique, we decided the femoral component rotation according to the ligament balance in flexion. Component and limb alignment are important considerations during TKA.Three-dimensional positioning of TKA implants and exact mechanical axis has an effect on implant loosening, polyethylene stresses, and gait.
According to the recent report, the navigation system made it possible to achieve aligned implants more than conventional TKA .Hybrid Navigation technique which is our procedure is combination of navigation system and modified gap technique.In other words, exact mechanical axis is gained by navigation system, stable stability of knee joint is gained by modified gap technique.
PURPOSE
The purpose of this study is to carry out clinical evaluation and image evaluation of the patients who underwent hybrid navigation technique TKA.
METHODS
We performed TKA using the hybrid navigation technique in 100 knees from April 2012 to April 2015. We evaluated hybrid navigation TKA which we were able to follow up more than five years.

33 knees were available for follow up. We investigated the mid-term results of TKA after a mean follow up period of 5 years and 8 months.We evaluated range of motion(ROM), Japan Orthopaedic Association (JOA)score, complications, revision rate as clinical evaluations. And we evaluated radiolucent line(RLL) ,loosening in X-ray, implantation accuracy in computed tomography(CT) as image evaluations.

Surgical technique was that the knees were exposed using a medial parapatellar approach without patella turnover, and the anterior and posterior cruciate ligaments were resected. And next osteotomy distal femur and proximal tibia using CT-free Navigation, step-wise medial soft tissue release was performed to make the rectangular extension joint gap using gap tensor space(off set balancer) at 40 pounds of distraction force. Flextion gap was made at the same distraction force,thereby we determined external rotation angle of femur osteotomy in a patella reduction position.
CT of the whole leg was taken preoperation and postoperationï¼ˆthe first postoperative weekï¼‰in all cases.
RESULTS
In CT evaluation,coronal and sagittal alignments of femoral componet were mean 90.92° and mean flex 3.02°.These alignment of tibial componet were 90.54° and mean posterior slope 3.0°.Outliers(>3°)of coronal aligment were 6% (2 knees)in femoral componet, and 6%(2 knees) in tibial componet.

In clinical evaluation,mean preoperative ROM(flex) was 105 degrees which improved 122 degrees at final follow up.Mean preoperative JOA score was 46.3 which improved 85.8 at final follow up.

In image evaluation,there were no incidence of component loosening(RLL>2mm).

We experienced two complications(1 deep infection and 1 intraoperative fracture), but there were no postoperative fracture and DVT/PE. The revision arte was 3%(1 knee) due to deep infection.

DISCUSSION AND CONCLUSION
Mid-term postoperative results has shown a good prognosis.We will not understand that we do not observe long-term results in future, neverthless we believe that this technique should be considered as an alternative means of conducting TKA.

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#5852

Effect of Osteophyte Removal on Deformity Correction and Gap Balance in Varus Knees During TKA

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Aims The aims of this prospective study were to determine the effect of osteophyte excision on deformity correction and soft-tissue gap balance in varus knees undergoing total knee arthroplasty (TKA).

Patients and Methods Limb deformity in coronal (varus) and sagittal (flexion) planes, medial and lateral gap distances in maximum knee extension and 90° knee flexion and maximum knee flexion were recorded before and after excision of medial femoral and tibial osteophytes using computer navigation in 164 patients who underwent 221 computer-assisted, cemented, cruciate-substituting TKAs.

Results Mean varus and flexion deformities of 4.5°±3° (0.5° to 30° varus) and 4.9°±5.9° (-15° hyperextension to 30° flexion) reduced significantly ($p<0.0001$) to mean varus deformity of 1°±2.3° and mean flexion deformity of 2.7°±4.2° after excision of medial femoral and tibial osteophytes. The mean medio-lateral (ML) soft-tissue gap difference in maximum knee extension and 90°knee flexion of 2.7±3.6mm and 0.7±2.6mm reduced significantly ($p<0.0001$) to mean ML soft-tissue gap difference of 0.7±2.5mm in maximum knee extension and 0.1±1.9mm in 90°knee flexion. The mean maximum knee flexion (122.8°±8.4°) increased significantly to mean maximum knee flexion of (125°±8°).

Conclusion Excision of medial femoral and tibial osteophytes during TKA in varus knees significantly improves varus and flexion deformities, mediolateral soft-tissue gap imbalance in maximum extension and in 90°knee flexion and maximum knee flexion.

Clinical Relevance Excision of medial femoral and tibial osteophytes can be a useful, initial step towards achieving deformity correction and gap balance without having to resort to soft-tissue release during TKA in varus knees.

Keywords: osteoarthritis, total knee arthroplasty, osteophyte, knee

#6050

On the Relationship Between Compartmental Loads and Gap Distance in the Coronal Plane During Instrumentation of Total Knee Arthroplasties

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Introduction: Robotic-assisted instrumentation and load sensors have been equated respectively with bony alignment and soft tissue balancing. Many surgeons use elements of both techniques, reflecting our incomplete understanding of the interactive forces during normal knee activity, and their effect on gap spaces and joint contact loads. Pure gap balancing may produce ligamentous tensile asymmetry, whereas pure distraction balance can cause mal-tracking. This article explores the relationship between gap distance and compartmental loads from an elementary mathematical perspective. The conclusions match experimental and known clinical findings.

Methods: The knee joint is simplified to a two-dimensional object with the femoral condyles represented as circles; dished tibial surfaces providing limited joint line congruency. The collateral ligaments are considered the major collateral forces. A varus loaded knee model is used to simulate force imbalance. The scenarios considered were neutral forces with low collateral tension, pre-liftoff forces, and post-liftoff forces.

Hypothesis: When the pre-tension of the collateral ligaments is significantly different, and the tight compartment is loaded to capacity, the compartment loads display clinically sub-optimal asymmetry despite gap balancing. For any gap balanced state, there are only a few clinically desirable possible compartmental load ratios. If excessive load differentials are associated with poor performance and satisfaction, then gap balancing alone cannot guarantee clinical success. Mathematically, the problem is to determine the relative loads generated by the model under reasonable assumptions for the biometric measurements of a knee and viscoelastic properties of the collateral ligaments.

Proof: Fig. 1 is a graphic representation of the free-body diagram of forces at work in a knee joint with double femoral condylar-to-tibia contact. Boundaries can be set for the gap distances and relative pre-tension of the collateral ligaments based on published and validated human dimensions and stress-strain curves. By varying these input parameters, clinically known scenarios can be generated, matching situations of pre- or post- lift-off asymmetry.

Results: As seen in Fig 2., under conditions of mid-tension of the MCL and low-tension of the LCL, there is a gradual but disproportionate overload on the medial side until theoretical failure of the ligament and subsequent shift in load dominance to the lateral side. The model predicts a LCL-to-MCL force ratio of 0.268:4.486. For the pre-liftoff state, the tighter side, the MCL here, reaches its elasticity limit. The knee is in double contact at rest but opens on the laxer side. Equal gap distance is possible, yet clinical testing shows asymmetry. Liftoff is not possible as long as the moment forces R1 and R2 about each condyle remain equal. The actual preservation of resting bicondylar contact is rooted in the disproportionate length of the lever arms acting on the medial condyle.

Conclusion: It is well known that up to 20% of knee arthroplasties fail early from instability not related to alignment. This study provides a mathematical model demonstrating such instability under specific clinical circumstances of ligamentous pre-tension imbalance despite gap balancing. The model can then be used to generate an individualized targeted soft tissue balance algorithm and better clinical outcome

Figures

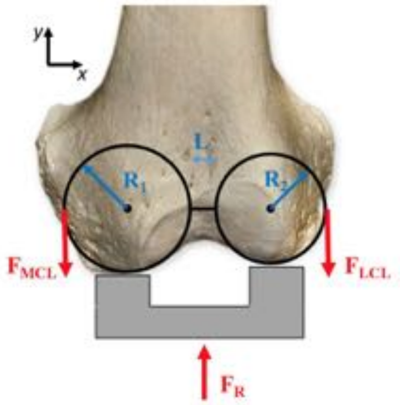

Fig 1: Schematic representation of compartmental loads of the femoral condyles during gap balancing, with medial and lateral condyles approximated by circles of radii R_1 and R_2, used to calculate the range of MCL to LCL forces.

Figure 1

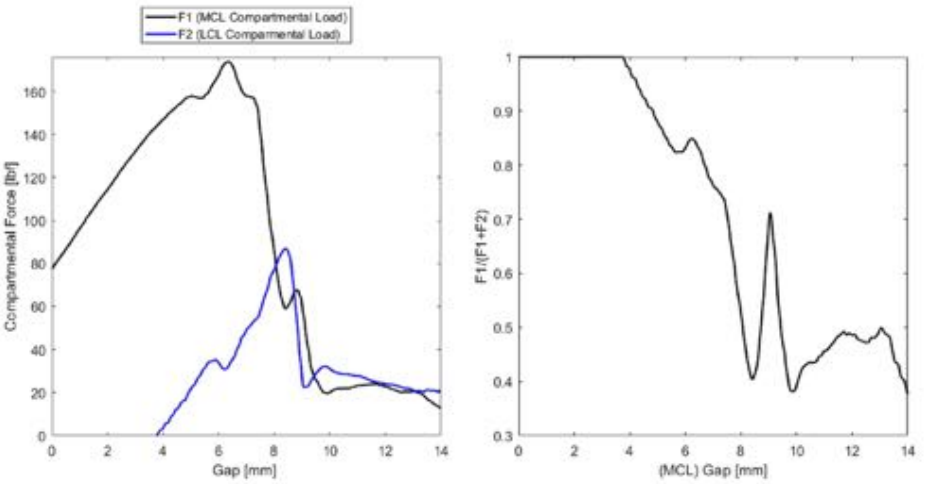

Fig. 2A Individual Compartmental Loads as a function of Gap Distraction

Fig. 2B Compartmental Load Distribution as a function of Gap Distraction

Figure 2

#5734

Effect of Posterior Cruciate Ligament Resection on Tibiofemoral Joint Gap in Varus Osteoarthritic Knees

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Introduction

In total knee arthroplasty (TKA), posterior cruciate ligament (PCL) resection has been considered to dominantly increase the tibiofemoral flexion gap compared to the extension gap. However, previous investigations have assessed this phenomenon after bone resections and soft-tissue release. Thus, this situation is considered abnormal and does not represent physiological knee kinematics. In this study, we hypothesized that PCL resection in which medial soft tissues are preserved does not affect the extension and flexion gaps. Therefore, we evaluated the effect of PCL resection, without any bone resection or soft-tissue release, on the tibiofemoral gap when osteophytes and medial soft-tissue conditions were similar to preoperative knee kinematics in osteoarthritic knees.

Patients and methods

Primary TKA patients with posterior-stabilized (PS) implants due to varus knee osteoarthritis (OA) were enrolled in this investigation. After knee arthrotomy, the medial joint capsule was subperiosteally separated 10 mm caudally from the tibial joint line reaching the anterior edge of the deep medial collateral ligament (dMCL); however, the dMCL itself was left intact. The anterior horn of the medial meniscus and the anterior segment of the lateral meniscus were excised to make space for insertion of a force-controlled ligament tensioner. At this stage, osteophytes of the femur and tibia, the dMCL, the superficial medial collateral ligament, the anterior cruciate ligament (ACL), and the PCL were not treated. The medial and lateral joint gaps were measured with the ligament tensioner in full extension and at 90° in flexion at a distracting force of 120 N. Throughout the study, to maintain the tibia's anteroposterior position relative to the femur when measuring the tibiofemoral joint gaps, after knee arthrotomy, the medial edges of the femur and tibia were marked with a surgical marking pen when extended as much as possible and at 90° flexion. The ACL and PCL were resected, and the tibiofemoral joint gaps were measured again.

Results

Analysis of the physiological gaps just after knee arthrotomy showed that the flexion gap was significantly larger than the extension gap in both medial and lateral compartments and was trapezoidal in shape, with the lateral compartment wider than the medial compartment in both extension and flexion. However, the results showed no clinically significant change of either the extension or the flexion gap in osteoarthritic knees by ACL and PCL resections.

Discussion

Although PCL resection is believed to increase the flexion gap more than the extension gap, in this study, it did not affect the extension or flexion gap. This contradiction is probably due to the existence of medial soft tissues. Recently, we performed TKAs with less soft-tissue release in order to preserve natural knee

kinematics. During the procedure, PCL resection did not increase the extension and flexion gaps. Therefore, TKA surgeons should carefully consider the distinct effects of PCL resection with and without medial soft-tissue release in TKA.

Conclusions

PCL resection does not affect the tibiofemoral gap in osteoarthritc knees when medial soft-tissue conditions are similar to preoperative osteoarthritic knee kinematics.

#6031

Pre-Operative Knee Laxity Measurements Are More Indicative of TKA Outcomes Than Intraoperative Assessments

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Introduction

Knee ligament laxity and soft tissue balance are important pre- and intra- operative balancing factors in total knee arthroplasty (TKA). Laxity can be measured pre-operatively from short-leg radiographs using a stress device to apply a reproducible force to the knee, whereas intra-operative laxity is routinely measured using a navigation system in which a variable surgeon-applied force is applied. The relationship between these two methods and TKA outcome however, has not been investigated. This study aims to determine how intra-operative assessments of laxity relate to functional radiographic assessments performed on pre-operatively. We also investigate how laxity relates to short-term patient-reported outcomes.

Method

A prospective consecutive study of 60 knees was performed. Eight weeks prior to surgery, patients had a CT scan and functional radiographs captured using a Telos stress device (Metax, Germany). This device applies a force to the knee joint while bracing the hip and ankle causing either a varus or valgus response.

3D bone models were segmented from the CT scan and landmarked to generate patient specific axes and alignments. Individual bone models were registered to the 2D stressed X-rays in flexion and extension. Reference axes identified on the registered 3D bone models were used to measure the coronal plane laxity. These laxity ranges were compared with those measured by a navigation system (OMNINAV, OMNI Life Science, MA) used during surgery, and Knee Injury and Osteoarthritis Outcome Scores (KOOS) captured 6 months postoperatively.

Results

Laxity measurements were acquired from 54 patients (58 knees; 4 bilaterals). The average age was 65±15 years old and 57% (n=31) of the patients were female.

The midpoints of the laxity curves generated by Telos and navigation techniques show significant strong correlations in extension ($r = 0.83$, $p < 0.001$) and flexion ($r = 0.53$, $p < 0.001$). However, the laxity ranges measured by the two techniques did not. On average the navigation system produced significantly larger laxity range measurements than the Telos stressed x-ray technique in both extension (Nav: 8.4° ± 2.0°; Telos: 4.0° ± 2.4°; $p < 0.001$) and flexion (Nav: 5.0 ± 2.4; Telos: 3.0 ± 2.4; $p < 0.001$).

Telos-generated laxity ranges indicate that patients who have initially greater laxity in extension than flexion (laxity range difference > 2°) have significantly better 6-month pain KOOS than those who show greater laxity in flexion (laxity range difference < -2°) ($p = 0.018$), see Figure 1. This correlation does not hold however, when examining laxity ranges generated by the navigation system, see Figure 2.

Discussion and Conclusions

Significantly larger navigation-generated laxity ranges may be caused by: variable forces applied by the surgeon while the patient is under anaesthetic, surpassing the patient's functional limit; as well as due to the altered physical state of the knee during surgery. More sophisticated techniques to reproducibly assess intra-operative soft tissue balance may be required to accurately define laxity range. Results indicate that functional Telos-generated laxity ranges may provide unique insight into the relationship between laxity and postoperative outcomes that cannot be attained with passive navigated measurements.

Figures

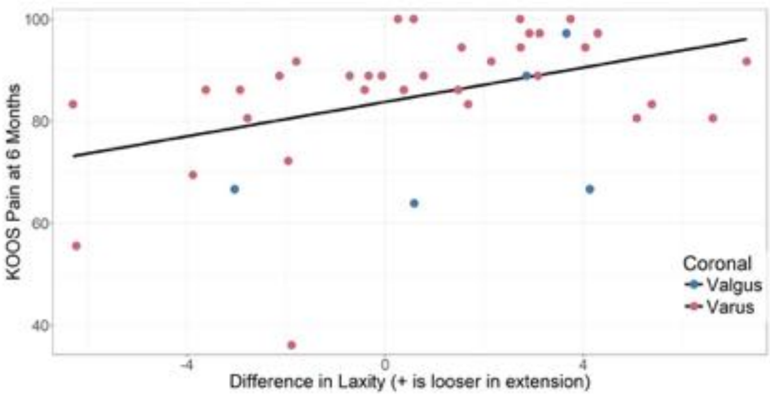

Figure 1 Change in laxity range from flexion to extension correlates with 6-months KOOS Pain. Patients with greater extension laxity range report improved outcomes.

Figure 1

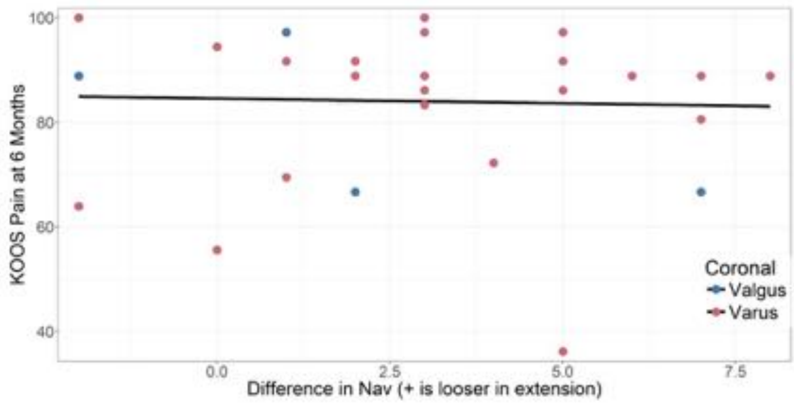

Figure 2 Change in laxity range from flexion to extension does not correlate with 6-months KOOS Pain, indicating the navigation reported laxity range is significantly different from the Telos reported laxity.

Figure 2

#5877

A Load Measuring Device Can Achieve Fine Tuning of Mediolateral Load at Knee Replacement but May Lead to a More Lax Knee State

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Purpose: The concept of a balanced knee remains poorly defined. With emergent robotic surgery and intra operative sensor technology, there is an opportunity to delineate the role of existing and novel balancing devices upon the final total knee replacement (TKR) construct. Balance across the replaced knee joint is classically determined through tension at full extension and 90 degrees and such distraction presumes equivalent Young's moduli for the medial and lateral soft tissue constraints. This is therefore an inferred measurement and may not accurately reflect the in vivo dynamic performance of the artificial joint. Our null hypothesis was that remote sensor directed total knee replacement could not offer an improvement in final load distribution after prosthetic implantation when compared to existing manually driven tensiometer devices. Load was determined using remote sensor real time trial inserts (VerasenseTM, Orthosensor). Methods: A cadaveric study, using 8 knees, was performed to define the impact of an established gap distraction device against load sensor aimed soft tissue release in a TKR setting. Using validated measures of laxity in 6 degrees of freedom and true real time load sensing 4 states were examined: native knee, TKA using spacer blocks (TKA), TKA with soft tissue release aided by monogram tensiometer (TKA-DB) and finally where load across the tibiofemoral articulation remains unbalanced final soft tissue release using a sensor device (TKA-OS). Sequence of procedures is given in Figure 1. Results: The laxity pattern was equivalent for TKA-DB and TKA-OS. However, in only 4 of these 7 knees despite the tensiometer confirming equivalence of rectangular flexion extension gap dimensions and centralisation of collateral ligament distraction, there remained a >15lb medial to lateral load difference for at least one point of the flexion arc. This was corrected by further final soft tissue release guided by the OS sensor device in the final 3 knees. Figure 2 outlines the change in load on the medial side for the 3 states through an arc of motion. No significant differences through the sequence of releases for load across the lateral compartment were found, Figure 3. Conclusion: Using measured resection and gap balancing there was completion of accepted standards for a balanced knee. The laxity pattern and load distribution was further improved with the use of a tensiometer to guide soft tissue tension balancing in distraction. However, in 3 out of 7 knee procedures additional soft tissue release was required to achieve equal mediolateral load distribution, as determined with the use of a VerasenseTM remote load measuring device, through a full functional arc.

Figures

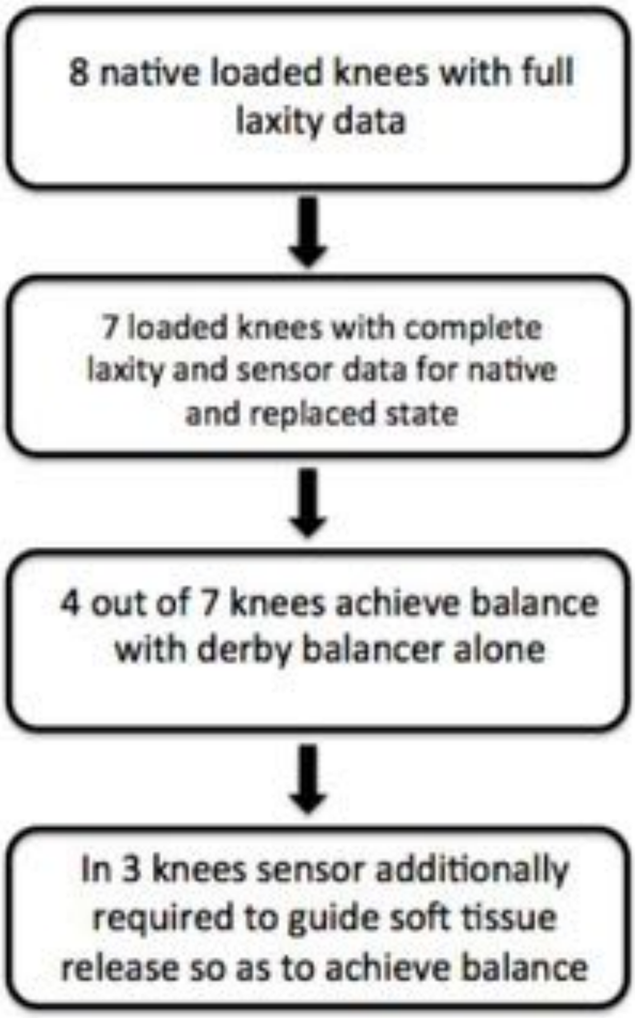
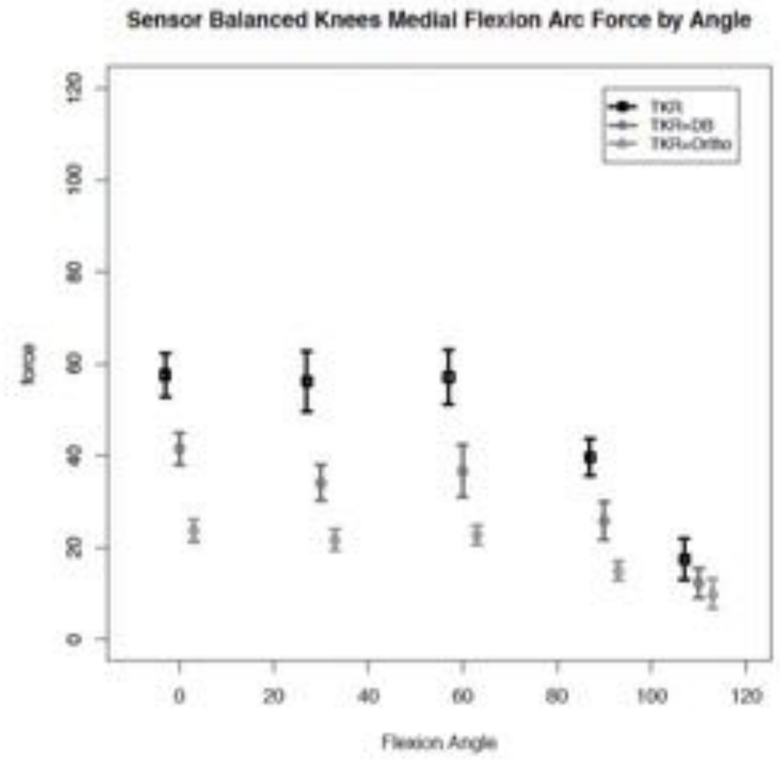

8 native loaded knees with full laxity data
7 loaded knees with complete laxity and sensor data for native and replaced state
4 out of 7 knees achieve balance with derby balancer alone
In 3 knees sensor additionally required to guide soft tissue release so as to achieve balance

Figure 1

Figure 2



[Figure 2](#)

Figure 3

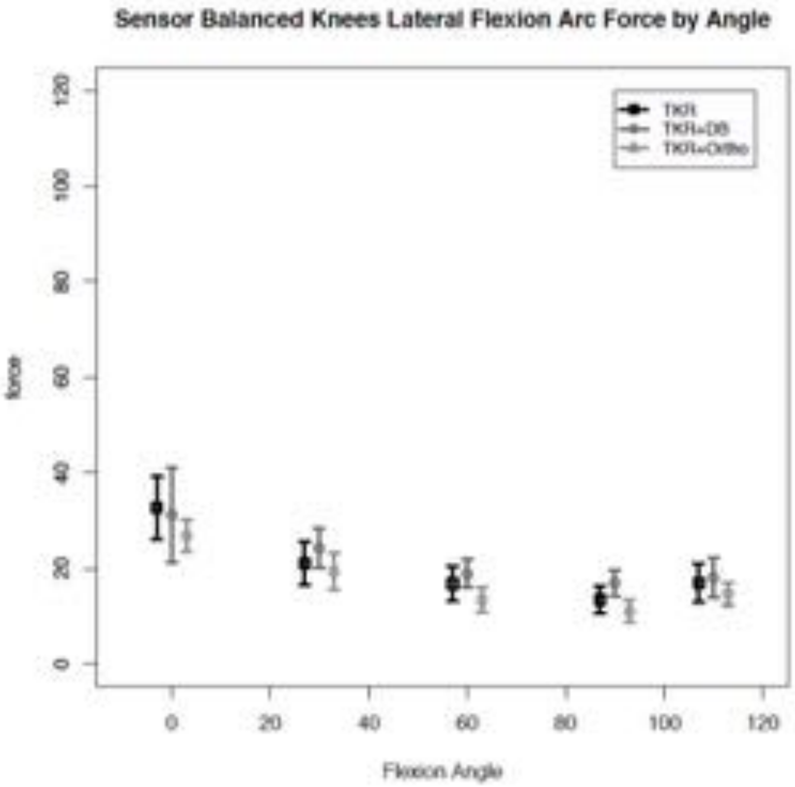


Figure 3

#6189

Correction of Alignment (HKA Angle) Predicts Reduction of Dynamic Loads in Gait Following Medial Unicompartmental Knee Replacement.

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Background: Alignment and soft tissue (ligament) balance are two variables that are under the control of a surgeon during replacement arthroplasty of the knee. Mobile bearing medial unicompartmental knee replacements have traditionally advocated sizing the prosthesis based on soft tissue balance while accepting the natural alignment of the knee, while fixed bearing prosthesis have tended to correct alignment to a pre planned value, while meticulously avoiding overcorrection. The dynamic loading parameters like peak adduction moment (PKAM) and angular adduction Impulse (Add Imp) have been studied extensively as proxies for medial compartment loading. In this investigation we tried to answer the question whether correcting static alignment, which is the only alignment variable under the control of the surgeon actually translates into improvement in dynamic loading during gait. We investigated the effect of correction of static alignment parameter Hip Knee Ankle (HKA) angle and dynamic alignment parameter in coronal plane, Mean Adduction angle (MAA) on 1st Peak Knee Adduction Moment (PKAM) and Angular Adduction Impulse (Add Imp) following medial unicompartmental knee replacements.

Methods: Twenty four knees (20 patients) underwent instrumented gait analysis(BTS Milan, 12 cameras and single Kistler force platform measuring at 100 Hz) before and after medial uni compartmental knee replacement. The alignment was measured using long leg alignment views, to assess Hip Knee Ankle (HKA) angle. Coronal plane kinetics namely 1st Peak Knee Adduction Moment (PKAM) and angular adduction impulse (Add Imp)- which is the moment time integral of the adduction moment curve were calculated to assess medial compartment loading. Single and multiple regression analyses were done to assess the effect of static alignment parameters (HKA angle) and dynamic coronal plane alignment parameters (Mean Adduction Angle – MAA) on PKAM and Add Imp.

Results: 12 knees had mobile bearing prosthesis implanted while the other 12 had fixed bearing prosthesis. The mean correction for HKA angle was 2.78 degrees (SD ± 1.32 degrees). There was no significant difference in correction of alignment (HKA) between mobile bearing and fixed bearing groups. MAA and HKA angles were significant predictors of dynamic loading parameters, PKAM and Add Imp ($p<0.05$). Correction of HKA angle was found to be a better predictor of dynamic loading.We assessed the percentage improvement in loading (%âˆ†PKAM & %âˆ†Add. Imp) and its relationship to correction of HKA (âˆ† HKA) angle Correction of alignment in the form of HKA (âˆ† HKA) angle was found to be a very strong predictor of improvement of loads (R = 0.90 for %âˆ†Add. Imp and R = 0.50 for %âˆ† PKAM).

Conclusion: Correction of alignment (HKA Angle) predicts improvement in loads through medial compartment of knee. One degree correction resulted in 7% improvement of load through the medial unicompartmental knee replacement.

UKA With Portable Navigation

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ã€Purposeã€'

From September in 2017, in the case of Persona partial Knee (Zimmer-Biomet Holdings, Inc.), we used portable navigation system (KneeAlign2 : OrthAlign Inc.)

We examined the setting precision (accuracy of tibial osteotomy) of the tibia component (Varus angle, Posterior Slope) and compared with the result of usual UKA (ZUK : Lima Inc.) without Navigation.

In either case, the aimed setting angle of the tibia component is 2.0 degrees varus, 7 degrees posterior slope.

ã€Objectã€'PPK with Navigation (P group) : 21 Cases 22 Knees, Usual UKA without Navigation (U group) : 17 cases 20 Knees. All cases were operated by single high volume surgeon (over 100 cases per year).

ã€Resultã€'

The average of varus angle were 3.1±1.4 degrees (P group) and 2.6±1.5 degrees (U group). The setting rate of error less than 2 degrees with the targeted value were 77% (P group) and 80% (U group). The setting rate of error less than 3 degrees with the targeted value were 100% (both group).

The average of Posterior slope were 5.9±2.0 degrees (P group) and 6.8±1.9 degrees (U group). The setting rate of error less than 2 degrees with the targeted value were 77% (P group) and 50% (U group). The setting rate of error less than 3 degrees with the targeted value were 96% (P group) and 95% (U group).

ã€Discussionã€'

In the accuracy of the tibia component setting and operation time, the significant difference was not seen between both groups. So UKA with portable navigation is approximately equal to high volume surgeon in the accuracy of tibial osteotomy.

For low volume surgeon, they can safely and accurately cut Tibia which is key point of MIS-UKA. We conclude that UKA with portable navigation is very effective for low volume surgeon, but not so effective for high volume surgeon.

#5690

Does Unicompartmental Knee Arthroplasty Have Worse Outcomes in Spontaneous Osteonecrosis of the Knee Than in Medial Compartment Osteoarthritis? a Systematic Review and Meta-Analysis

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The role of unicompartmental knee arthroplasty (UKA) in spontaneous osteonecrosis of the knee (SONK) remains controversial, even though SONK usually involves only medial compartment of the knee joint. We aimed to compare the survival rate and clinical outcomes of UKA in SONK and medial compartment osteoarthritis (MOA) via a meta-analysis of previous studies. MEDLINE database in PubMed, the Embase database, and the Cochrane Library were searched up to January 2018 with keywords related to SONK and UKA. Studies were selected with predetermined inclusion criteria: (1) medial UKA as the primary procedure, (2) reporting implant survival or clinical outcomes of osteonecrosis and osteoarthritis, and (3) follow-up period greater than 1 year. Quality assessment was performed using the risk of bias assessment tool for non-randomised studies (RoBANs). A random effects model was used to estimate the pooled relative risk (RR) and standardised mean difference. The incidence of UKA revision for any reason was significantly higher in SONK than in MOA group (pooled RR = 1.83, $p = 0.009$). However, the risk of revision due to aseptic loosening and all-cause re-operation was not significantly different between the groups. Moreover, when stratified by the study quality, high quality studies showed similar risk of overall revision in SONK and MOA ($p = 0.71$). Subgroup analysis revealed worse survival of SONK, mainly related to high failure after uncemented UKA. Clinical outcomes after UKA were similar between SONK and MOA ($p = 0.66$). Cemented UKA has similar survival and clinical outcomes in SONK and MOA. Prospective studies designed specifically to compare the UKA outcomes in SONK and MOA are necessary.

Fig. 1. Risk of bias assessment using risk of bias assessment tool for non-randomised studies (RoBANS)

(a) Review of the author's judgment about each risk of bias item for each included studies; (b) Review of the author's judgment about each risk of bias item presented as percentages across all included studies

Fig. 2. Results of unicompartmental knee arthroplasty in spontaneous osteonecrosis of the knee and in medial osteoarthritis

(a) Revision for any reason; (b) Revision due to aseptic loosening; (c) All-cause re-operation risk ratio

Fig. 3. Funnel plot showing publication bias

Fig. 4. Forest plots showing pooled risk ratio of revision for any reason in three subgroups: studies performed using cemented mobile bearing implant, cemented fixed bearing implant, or uncemented implant

Fig. 5. Forest plots demonstrating standardised mean difference between spontaneous osteonecrosis of the knee and medial osteoarthritis

(a) Range of motion; (b) Clinical outcome scores

Figures

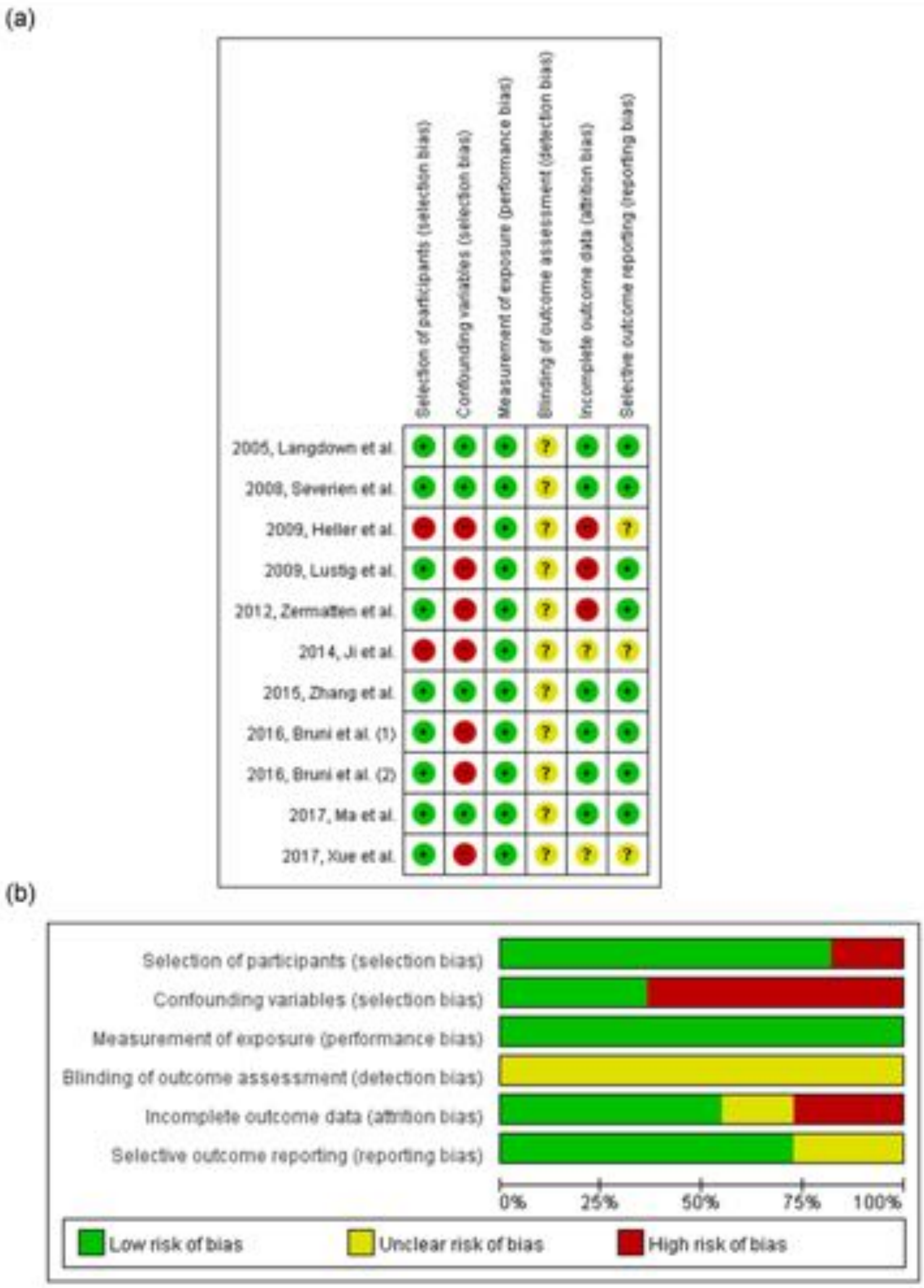
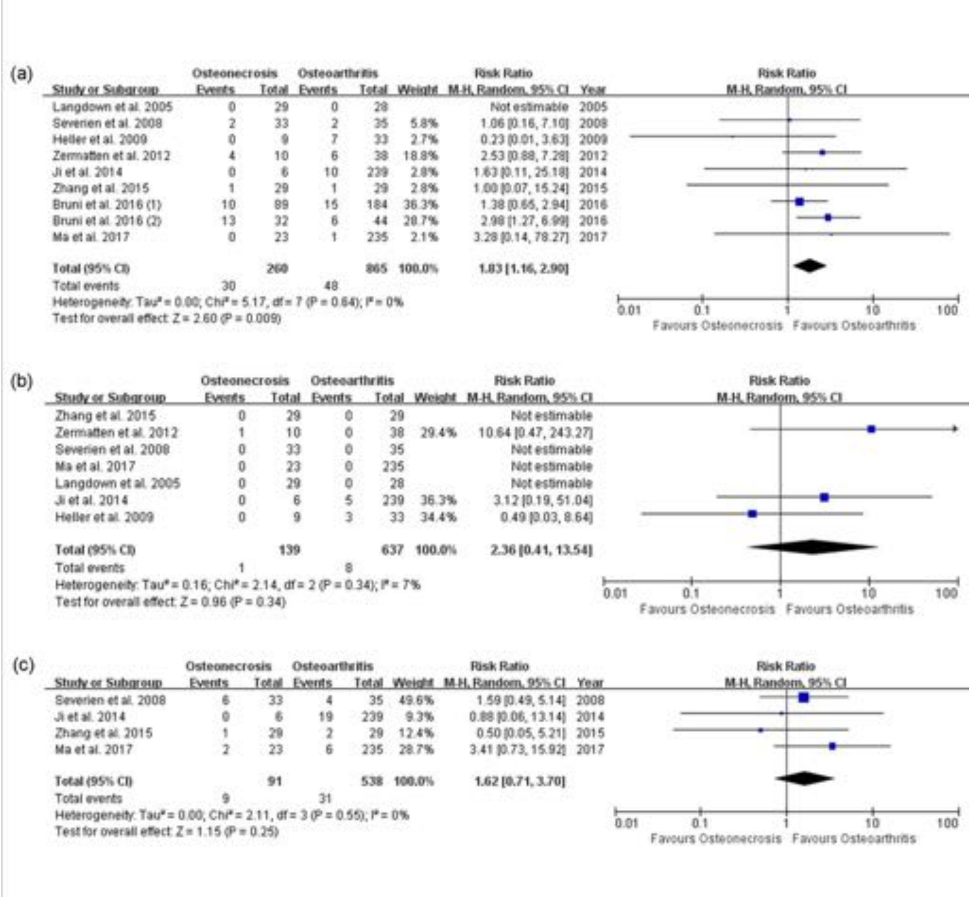
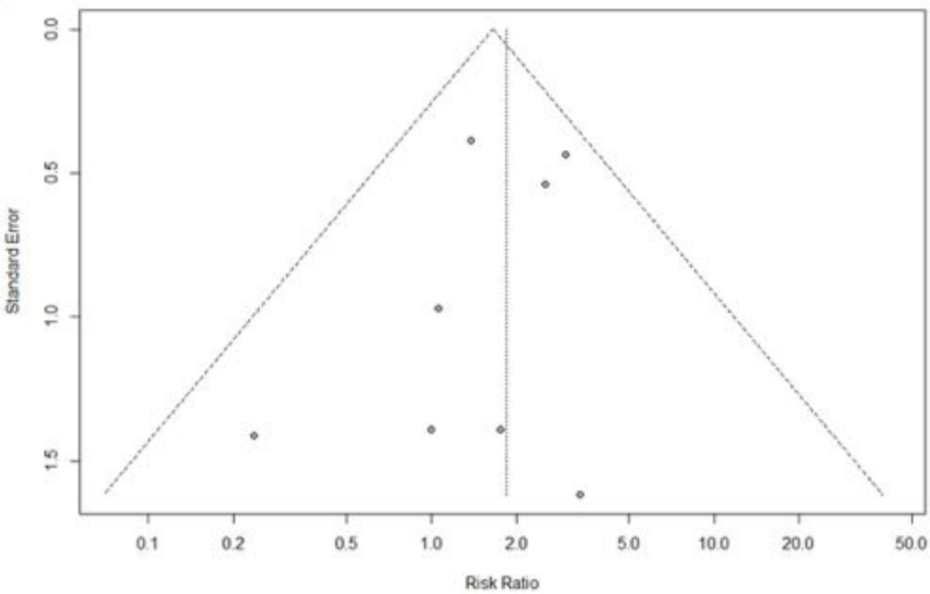


Figure 1



[Figure 2](#)



[Figure 3](#)

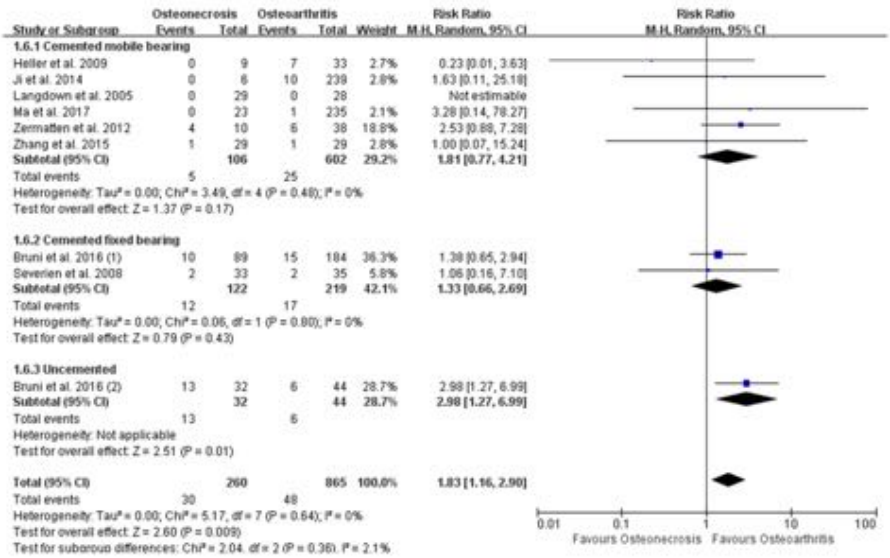


Figure 4

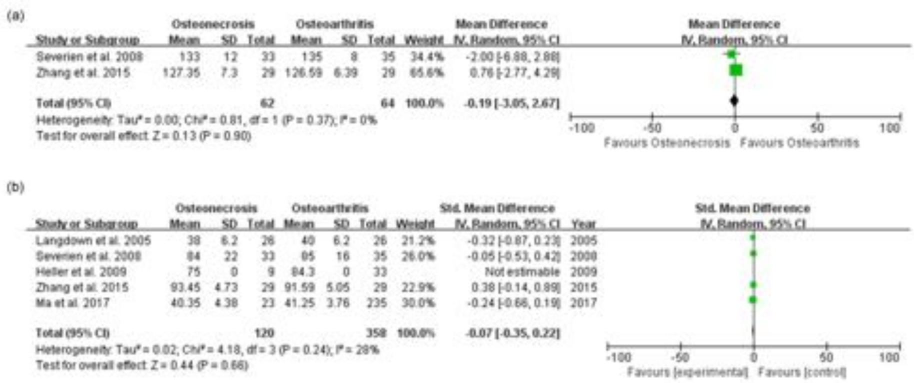


Figure 5

#5654

The Relationship Between the Alignment of UKA Component and Radiolucent Line

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INTRODUCTION

A radiolucent line (RLL) is often seen under the tibial component after unicompartmental knee arthroplasty (UKA). The relationship between the alignment of UKA and RLL is not resolved. In this study, we evaluated the relationship by 3D template software.

PATIENTS

We investigated 40 Japanese patients, 8 male patients and 32 female patients, who underwent medial UKA in our department between January 2014 and December 2015. All patients were diagnosed with medial compartment osteoarthritis. The average age was 73(range: 61-86) years old. We used Unicompartmental High Flex Knee made by Zimmer Corporation, which is fixed bearing type UKA, for all patients. All patients had a follow-up longer than 12 months. The average was 32 (range: 12-48) months.

METHODS

We measured the three dimensional alignment of the femoral and tibial components from postoperative CT scan with 3D template software, ZedKnee made by LEXI Corporation. Moreover, we evaluated RLL from X-ray of the latest follow-up. Patients were divided into RLL (+) group and RLL (-) group. We examined the relationship with RLL and the alignment of components.

RESULTS

RLL was appeared in 9 knees (22.5%). In RLL(+) group, the mean angles of femoral components were 3.9 degrees in varus, 1.6 degrees in flexion, and 1.8 degrees in external rotation. The mean angles of tibial components were 3.9 degrees in varus, 5.5 degrees in posterior slope, and 5.3 degrees in external rotation. In RLL(-) group, the mean angles of femoral components were 2.5 degrees in varus, 2.5 degrees in flexion, and 2.1 degrees in external rotation. The mean angles of tibial components were 3.3 degrees in varus, 7.5 degrees in posterior slope, and 5.1 degrees in external rotation. There was a significant difference only in the average posterior slope angle of the tibial components ($p<0.01$).

CONCLUSION

The average posterior slope angle of the tibial components was significantly lower in RLL(+) group. It was thought that the stress for the posterior tibia by the less posterior slope increased the RLL under the tibial components after UKA.

#5718

A Case of Pseudomeniscus Impingement After Unicompartmental Knee Arthroplasty

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Unicompartmental knee arthroplasty (UKA) is one of the main treatment options for unicompartmental knee osteoarthritis, and good clinical results were reported. However, UKA also has some difficulties in the surgical techniques, and it has been reported migration of prosthesis, aseptic loosening and polyethylene bearing dislocation, a loose body, meniscus rupture as causes of persistent postoperative pain. We present an infrequent case of pseudomeniscus impingement as a consequence of inadequate soft tissue dissection and posterior overhanging of the tibial component.

A 76-year-old male patient with isolated medial compartment osteoarthritis of the left knee underwent UKA using Unicompartmental High Flex Knee (Zimmer, Warsaw, Indiana, USA) 4 years ago. The postoperative course was uneventful, but approximately 3 years after surgery he presented with catching and pain in the medial aspect of his knee. On clinical examination, tenderness on the medial joint line was noted. And the McMurray test revealed clicking and corresponding pain in the posteromedial part of the knee joint. An infection workup was performed, including complete blood counts, erythrocyte sedimentation rate, C-reactive protein, the results for all of which proved negative. Radiographs revealed a cemented left UKA with good alignment and without evidence of loosening, polyethylene wear or loose bodies. Plain computed tomography (CT) showed the tibial component with a 1.7 mm posterior overhang. An injection test consisting of administration of 1% lidocaine at the medial joint line yielded moderate relief.

Under the suspicion of soft tissue impingement, diagnostic arthroscopy was performed using standard anterolateral and anteromedial portals. This confirmed that the pseudomeniscus-like soft tissue in the posteromedial compartment was observed to impinge between the femoral component and the polyethylene tibial spacer. By use of punch and shaver, this soft tissue was excised to its rim so that it no longer impinged in any position. A histologic evaluation of the excised tissue showed that it was composed of fibrous tissue with a synovial tissue. The patient remained free of complaints 2 year postoperatively.

Symptomatic pseudomeniscus impingement is one of several postoperative complications of knee arthroplasty that can be successfully diagnosed and treated arthroscopically.

#5739

Second Surgery Following Partial Knee Replacement Is Functionally Superior With Higher Patient Satisfaction Than Primary Total Knee Replacement

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Background:

The National Joint Registry regards second surgery in a joint that has previously undergone Partial Knee Replacement (PKR) as ‘revision surgery’ and, ultimately, failure of the primary procedure. The term ‘revision’ encompasses a heterogeneous group of procedures: conversion to Total Knee Replacement (TKR), meniscal bearing exchange, PKR component exchange (conversion of mobile to fixed bearing, for example) or the primary PKR may be left untouched, yet still branded a failure, and a second PKR ‘added’ to a newly degenerate native compartment. Here, the arthroplasty is converted to a Bi-Unicondylar or Bi-Compartmental replacement. We hypothesise that the outcome of further surgery may be superior, in terms of objective function and patient satisfaction, to that of primary TKR.

Methods

All revision PKRs performed by the senior author over the last ten years were reviewed. Outcome of revision PKR was assessed objectively in the gait lab using standard metrics, compared to primary TKRs and healthy controls, matched for age and Body Mass Index. Subjectively, outcomes were assessed using the Oxford Knee Score (OKS.)

Results

Of 1374 patients undergoing knee surgery, 143 revision arthroplasty procedures were undertaken. Primary procedures were carried out by a number of surgeons at different centres. Of the procedures, 24 PKR to TKR procedures were performed; 32 meniscal bearing exchanges occurred, 28 PKRs had revision of a component to another PKR and 39 underwent addition of PKR procedures, and hence, conversion to combined PKR. Twenty patients had revision of an existing TKR and were excluded.

Objectively, in the gait laboratory, at 4Km/hr we were unable to show a statistical difference between the matched groups (15 Healthy controls vs 22 Revision PKR vs 16 Primary TKR) except for a functional advantage of controls and revisions over TKR during mid-stance ($p = 0.01$). However, Healthy controls had a median top walking speed (TWS) of 7.5Km/h, Revision PKR of 6.5Km/h and TKR of 5.8Km/h. Revision PKR walked 10% faster than TKR. At TWS (Figure 1.) the Revision PKR group walked in a statistically similar way to healthy controls, whereas TKR was significantly abnormal in terms of weight acceptance ($p=0.03$) heel strike ($p=0.003$) mid-stance ($p=0.001$) step length ($p<0.001$) and contact time ($p<0.001$.) Of the Revision PKR group, 11 patients had undergone conversion to combined PKR and mirrored the gait of the revision PKR group, statistically similar to healthy controls, functionally superior to primary TKR. Subjectively, revised PKRs were associated with significantly higher patient satisfaction (Mean OKS 41.5, Median 42) than over 96,000 primary TKRs reported in fiver papers in the literature (Table 1.)

Conclusion

PKRs subject to re-operation continue to function better than primary TKAs. Even after multiple small operations, patients remain more mobile and satisfied. The threshold for surgery may be lower if revision does not mean TKR. The addition of a further PKA appears to be functionally effective for selected patients.

Figures

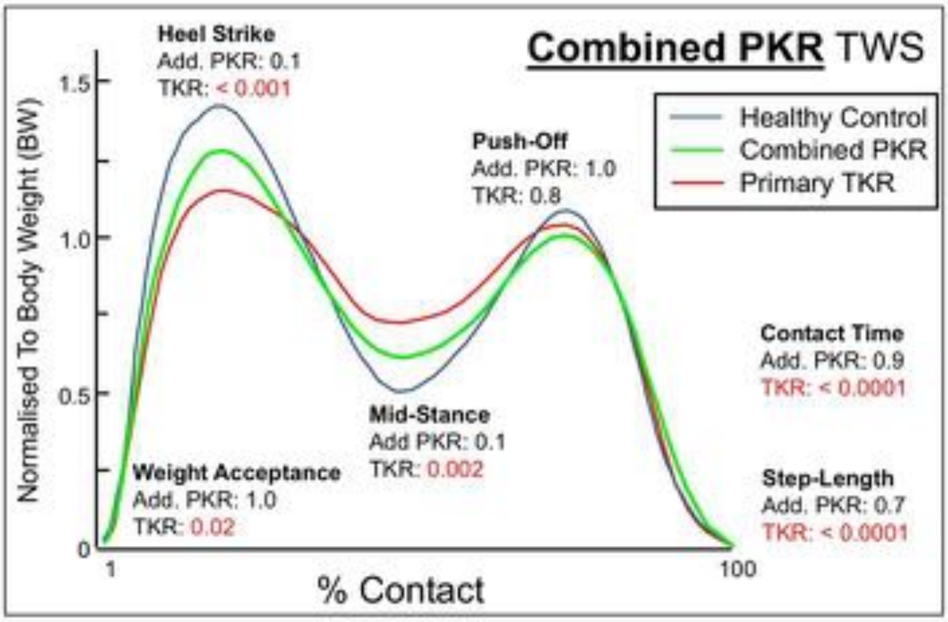

Figure 1. Ground Reaction Force and Standard Metrics of Gait for Healthy Controls Compared to Revision Partial Knee Replacements and Primary Total Knee Replacements at Top Walking Speeds (TWS)

Figure 1

Publication	n =	Time Post Op (Months)	Mean OKS	p value
This Study	n = 22	36	41.5	
Liddle et. al 2015	55,208	6	34.9	0.001
Petersen et. al 2017	57	6	36.8	0.005
HES 2012 / 2013	39,736	12	33.9	< 0.0001
Breeman et. al 2013	276	12	33.4	0.001
	276	24	34.2	0.001
Williams et. al 2013	676	24	34.4	< 0.0001

Table 1. Oxford Knee Score of Revision Partial Knee Replacements Compared to Literature Values of Primary Total Knee Replacement.

Figure 2

#5589

Long-Term Results of Mobile-Bearing Unicompartmental Knee Arthroplasty for Spontaneous Osteonecrosis of the Knee

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Aims

Spontaneous osteonecrosis of the knee (SONK) mainly affects the medial femoral condyle, would be a good indication for UKA. The clinical outcome and remaining problems of the UKA for SONK should be clarified.

Patients and Methods

We reviewed 50 knees who were treated for SONK. Patients included ten males and 38 females. The mean age was 73 years (range, 57 to 83 years). The mean height and body weight were, respectively 153 cm and 57 kg. All had been operated on using the Oxford mobile-bearing UKA (Zimmer-Biomet, Swindon, United Kingdom). The mean follow-up period was 9 years (range, 4 to 15years). We measured the size (width, length and depth) and the volume to be estimated (width x length x depth) of the necrotic bone mass using MRI in T1-weighted images.

The clinical results were evaluated using the Knee Society Scoring System (KSS) and Oxford Knee Score (OKS). The flexion angle of the knee was evaluated using lateral X-ray images in maximum flexion.

Results

There were no implant failures, but there were 4 deaths (from causes unrelated to UKA) mean 6.6 years after surgery(5~8), 3 cases were lost mean 3.3 years after surgery(2~5). The mean size of the necrotic lesion were 17.2mm (14.7~25.3) in width, 28.2mm (6.2~38.3) in length and 11.3mm (3.2~14.3) in depth. The mean volume of it was calculated to be approximate 5.4 cm3 (0.7~11.1). The mean flexion of the knee , KSS Knee Score, Function Score and OKS increased from a preoperative 128.7 degrees to 137.5 degrees, 52.3 to 91.3, 39.7 to 90.2 and 21.6 to 41.2, respectively at the latest follow-up.

Conclusions

The Oxford mobile-bearing UKA for SONK gave results similar to those obtained when it was used for patients with primary osteoarthritis, and no significant problems were noted in this study.

#5914

Accuracy of Intraoperative Robotic-Arm Assisted Unicompartmental Knee Replacement Coronal Alignment With Standing Long Leg Postoperative Alignment

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Purpose: Unicompartmental knee arthroplasty (UKA) is performed for patients experiencing

arthritic pain in either medial or lateral knee compartments. Errors in coronal alignment with conventional instrumentation leading to under or over correction can lead to accelerated implant wear or progression of osteoarthritis, in the contralateral compartment respectively. Robotic-Arm assisted UKA surgery has been shown improve accuracy and reproducibility of implant placement and limb alignment. The purpose of this study was to determine the accuracy of Robotic-Arm assisted UKA final limb intra-operative alignment to six-week postoperative standing long leg x-ray alignment.

Materials and Methods: A retrospective review of 63 robotic-arm assisted UKA procedures was performed. All surgeries were performed at one institution and by the same surgeon. Intraoperative alignment was obtained through CT based measurements, IR navigation and robotic-arm software. Postoperative alignment was obtained through long leg weight bearing x-rays taken at six weeks follow up. The mechanical axis was calculated by drawing a line from the center of the femoral head to the intercondylar notch of the distal femur to the center of the ankle. Statistical analysis was primarily descriptive with t-tests being utilized where appropriate.

Results: There were a total of 83 knees (43 right; 40 left) with a mean age of 71.84 $\pm$ 10.42 years. Mean intraoperative alignment was 4.03° $\pm$ 2.01° with a mean 6-week postoperative alignment of 3.09° $\pm$ 2.09°. There was an overall average change in alignment of 0.94° (left: 1.008°, right: 0.85°). There was a comparative mean difference of 0.94° $\pm$ 0.08° ($p < 0.001$).

Conclusion: Robotic-arm assisted surgery for UKA illustrates excellent intra-operative to post-operative alignment coronal alignment consistency. There was minimal difference in alignment when comparing measurements of intraoperative to postoperative weight-bearing views at six-weeks. Pre-operative deformity, and medial or lateral implantation did not affect the final alignment correlation. Our findings suggest that accurate implant and limb positioning intraoperatively with the assistance of the robot-arm CT based navigation will be achived in post-operative stance phase. Longer term outcomes are required to determine if this accuracy improves implant survivorship.

#6098

New Evidence of Adverse 3rd-Body Wear Mechanisms in Large-Diameter MOM Retrievals

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Demise of 2nd generation metal-on-metal bearings (MOM) was defined by biological ARMD risks, believed partially due to (i) cup edge-loading and (ii) fretting of THA trunnions. Seldom introduced were risks of (iii) CoCr particles released at hip impingement and (iii) adverse 3rd-body wear. In this retrieval study of four MOM brands (Biomet, Depuy, Smith & Nephew, and Zimmer), microscopic evidence was documented for risks (iii) and (iv) in failed, large-diameter MOM devices.

Study of CoCr scratch anatomy revealed multitudes of pits in femoral heads where large metal particles had impacted (Fig. 1A: pit-1). In this 44mm example, a particle had ploughed showed across the CoCr surface (Fig. 1E). Details revealed 4um pit depth (Figs. 1B, C) with 1.5um elevation of a plastically-deformed rim (Fig. 1B: #2), arrows indicating direction of rim/shoulder deformation (Fig. 1B). Note the scratch deepened as particle ploughed across the surface (Fig. 1C). A salient feature of this scratch was 120um width with a plastically-deformed 2um-rim on a 40um-wide plastically-deformed buttress (Fig. 1E: #7). Inferior and habitual 'non-wear zones' of femoral heads were particularly interesting because such areas could not be polished smooth during activities of daily living. Frequently these regions featured large pits at head base (Figs. 2A-C) with linear grooves emanating radially superiorly (Figs. 2D-F). Such 'basal' scratches frequently appeared as 'twins' (Figs. 2D-E), varied 100-300um wide, with 4 to 15um depth (Figs. 2C, F), featuring striated side walls (Fig. 2G). Worn regions on 'polar' aspects of heads were also informative, revealing many intersecting micro-grooves (Fig. 3). This 38mm head showed one small groove intersecting another 300um wide (Fig. 3B: 15um depth). The ploughing action of the large metal particle ((Fig. 3A: #1 imagined) created deep striations with the resulting CoCr matrix-deformation flowing into the larger groove (Fig. 3A: #2). SEM imaging showed the true scale, dwarfing many surface carbide formations.

This 1st demonstration of large particles ploughing into MOM retrievals revealed attendant plastic deformation with release of copious debris. Standard studies of MOM wear and effects of trunnion corrosion have described small particulates. CoCr debris from simulators (39mm, 55mm MOM) typically ranged 9 to 108nm with 28nm mean size. [Leslie 2008] In contrast, micro-grooves described in our MOM retrievals averaged 100um wide. These data indicated CoCr debris released clinically were approximately 3,000-fold larger(!) than in simulator tests. Impingement studies of MOM have shown cup rim-wear and neck-notching could be two sources of large particles.[Iida2005; Clarke2014] It was also hypothesized that such large particles fragmented and ionized with further activity.[Clarke2013] Analogous simulator studies using large metal particulates produced adverse MOM wear, turning lubricants black over 5-million cycles duration (Halim2015). It was noted that transfer of Ti6Al4V debris with impingement produced adverse wear as CoCr particulates. Conversely, simulator studies of edge-loaded cups, also 5-million cycle tests, did not reproduce such adverse results. [Williams2008; Angadji2009; Clarke2017]. Therefore, we hypothesize that risks resulting from (i) metal-metal impingement, (ii) release of large metal particulates, and (iii) 3rd-body wear appeared as a higher clinical risk than edge-loading studies would indicate.

Figures

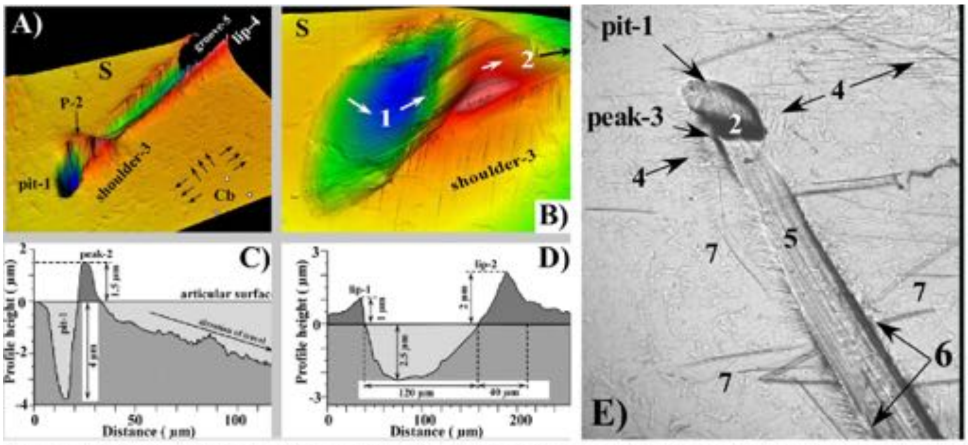


Fig. 1. Anatomy of large femoral-head scratch (44mm Magnum, Biomet): (A) Interferometry: oblique view of pit and scratch, (B) details of pit and deformed shoulder, (C) cross-section of pit and scratch, (D) 120µm wide scratch cross-section, and (E) light microscopy: pit and extended scratch details.

Figure 1

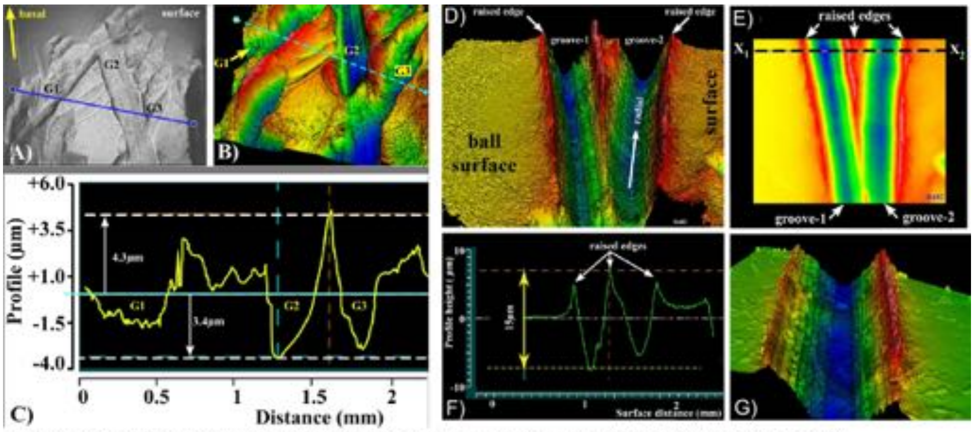
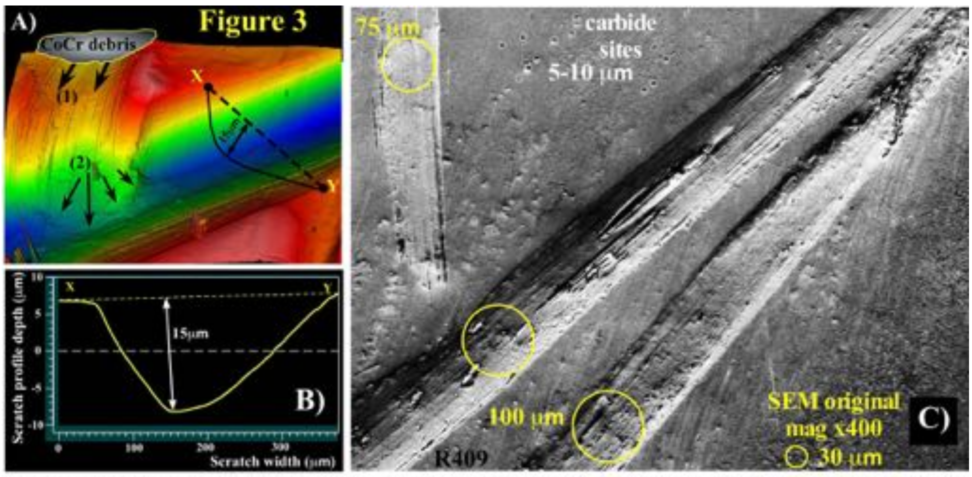


Fig. 2. Base of femoral head at inferior non-wear region (44mm Magnum, Biomet): (A, B) Interferometry of basal damage, (C) profile of damage, (D, E) twin scratches emanating in radial direction, (F) profile of scratches 300µm wide, 15µm deep, and (G) striated sidewalls.

Figure 2



Interferometry of intersecting scratches (38mm Biomet) depicts, A) cartoon of 150µm CoCr particle, (B) profile of 300µm groove (X-Y), (C) SEM: scratch 75µm wide, twins 100µm wide

Figure 3

Acknowledgements

This study was funded partially by contract FDA-1090372, Arthroplasty for Arthritis Foundation (UK-1051165), and DARF Center for Retrieval Analyses.

Figure 4

#5790

A Retrieval Analysis of Oxinium Heads: Do Oxinium Heads Decrease Tribocorrosion in Total Hip Arthroplasty?

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BACKGROUND: Trunnionosis is an important failure mechanism of total hip arthroplasties (THA) as has recently been reported by the England and Wales national joint registry. Adverse local tissue reaction has also recently been associated with metal on polyethylene and ceramic on polyethylene THA articulations. The contributing factors in the mechanism of this failure pattern have not been elucidated, however they are likely multifactorial to include corrosion, fretting, taper design, implantation time, metal particulate debris, and wear at the metal on metal interface. Furthermore, dissimilar metallic combinations have been shown to exacerbate tribocorrosion. Authors have also reported on the use of ceramic heads to reduce trunnionosis; however, tribocorrosion is still present. The majority of the literature regarding modular head neck taper fretting and corrosion involves cobalt chrome (CoCr) alloy. Little is known about head neck fretting corrosion with Oxinium femoral heads.

QUESTIONS/PURPOSE: To measure fretting, corrosion, and wear on the female tapers of retrieved Oxinium femoral heads and to determine how demographic and device factors affect these measurements.

METHODS: Ninety-two (92) retrieved 12/14 Oxinium heads were graded using the modified Goldberg score for subjectively grading corrosion and fretting on the taper surface. A novel silicone molding technique was validated, then applied to the female tapers of the retrievals and two pristine Oxinium femoral heads. The molds were scanned using a Konica Minolta 3D laser scanner for reconstruction of the topography, dimensions, and surface features of the tapers. Geomagic software was used to align the retrieved to the pristine 3D models, allowing measurement of surface deviations (from wear) that had occurred while the heads were implanted. Patient demographic and implant data were correlated with Goldberg scores and wear deviations.

RESULTS: The mean Goldberg score was 1.6. Goldberg scores of 1 (minimal), 2 (mild), and 3 (moderate) were present in 41 of the 92 heads (45%), 43 heads (47%), and 8 heads (8%), respectively. No implants received a score of 4 (severe). A positive significant correlation was found between length of implantation and increased female taper fretting (ð'…=0.436, $p<0.01$). Wear deviations were significantly greater with 36mm heads compared to 32mm heads ($p<0.05$) and with +4 offsets compared to 0 offsets ($p=0.013$).

CONCLUSIONS: Similar to previous work analyzing ceramic heads, Oxinium heads demonstrated predominately mild tribocorrosion grades however do not eliminate tribocorrosion. Tribocorrosion was increased with large heads and increased offsets. This finding is consistent perhaps with greater mechanical burden that larger implants with increased offsets experience. Further investigation is needed to elucidate if Oxinium femoral heads reduce fretting and corrosion when compared to CoCr femoral heads.

#6172

Unequivocal Retrieval Evidence That Metal-Rimmed Hip Liners and Acetabular Shells Promote Release of Large Metal Particles During Repetitively Consistent Impingement Episodes

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Metal-on-metal (MOM) arthroplasty has been abandoned, but many patients remain at risk. In analyzing CoCr wear and failures, ‘edge-loading’ and ‘trunnion-corrosion’ received great attention. However, such effects typically produce small metal particles. Simulator/clinical reports were supportive of this, describing CoCr particles averaging 24nm-40nm.[Leslie2008; Doorn1998]. However, we have documented that retrieved MOM bearings featured large scratches 40-100um wide, i.e. more than x1,000 times larger.[Howie2005; Clarke2013] These were barely visible to naked eye, so we termed as “microgrooves”. [Clarke2013] Typically, retrieval studies have proposed that such large scratches were caused by (i) patient dislocations, (ii) plastic-deformation, and (iii) heads damaged at revision. In this report we offer unequivocal evidence that cup-rim wear on a metal femoral-neck represents (i) characteristic impingement sites, (ii) potential for head-subluxation, and (ii) large debris.

Three MOM retrieval cases will be presented with evidence of multiple impingements, two with notched CoCr necks and one with Ti6Al4V neck. Damaged areas were replicated and imaged by interferometry and SEM. Wear-volumes and release-rates of metal-debris were modelled. Concept of cup sliding/wearing on the femoral neck will be termed ‘wear impinging & notching’ (WIN).

Revision of a 28mm MOM implanted in an active female patient demonstrated three neck notches. Notch #1 on this CoCr neck was positioned superiorly on same radius as head (Fig. 1A: #1). With cup positioned at 38^{o}polar incidence, the rim superimposed on posterior notch #2 (Figs. 1B, C). The cup rim superimposed on distal notch #3 at 13^{o}incidence (Figs. 1B, D). Two notches were unequivocal evidence of head subluxation creating three WIN-effects (Fig. 1D). In contrast, cup-rim wear was unremarkable.

In 2ndexample, a 28mm MOM implanted in a female with multiple medical problems, created implant noises and high metal ions, and was revised for pain after 3 years (Fig. 2A). Her notched femoral-neck had three facets that spanned 7.3mm (Fig. 2B). Replicas of CoCr liner and its Ti6Al4V shell revealed its rim-profile (Fig. 2C) corresponded to neck-notch profile (Fig. 2B). This correspondence was unequivocal evidence of repetitive and consistent WIN-effect, analogous indeed to precision-machining in a Ti6Al4V neck. Volume of debris released was estimated at 20mm^3. This would be analogous to release of approximately 300,000 of 50-um size particles, or 40,000 of 100-um size. Wear of the CoCr liner rim was unremarkable. The 3rd example illustrated that even Bipolar cups designed with large range-of-motion can also notch CoCr necks (Fig. 3). In this case the larger shell created the notch more distal than usual.

In conclusion, few studies have implicated hip impingement and femoral-neck damage with release of metal particulates.[Walker1971; Clarke2003; Howie 2005] Retrieval evidence was unequivocal, that (i) femoral-neck notching occurred at impingement sites with metal cup-liners or shells, (ii) occurred on CoCr and Ti6Al4V necks, (iii) was a repetitive and precise wear-process (WIN), releasing clinically relevant volumes of metal particulates. The WIN-process was undoubtedly an aggressive wear process over time that released large metal particles that ploughed CoCr surfaces, thereby forming the ‘microgrooves’, evidence of an adverse 3rd body wear mechanism.

Figures

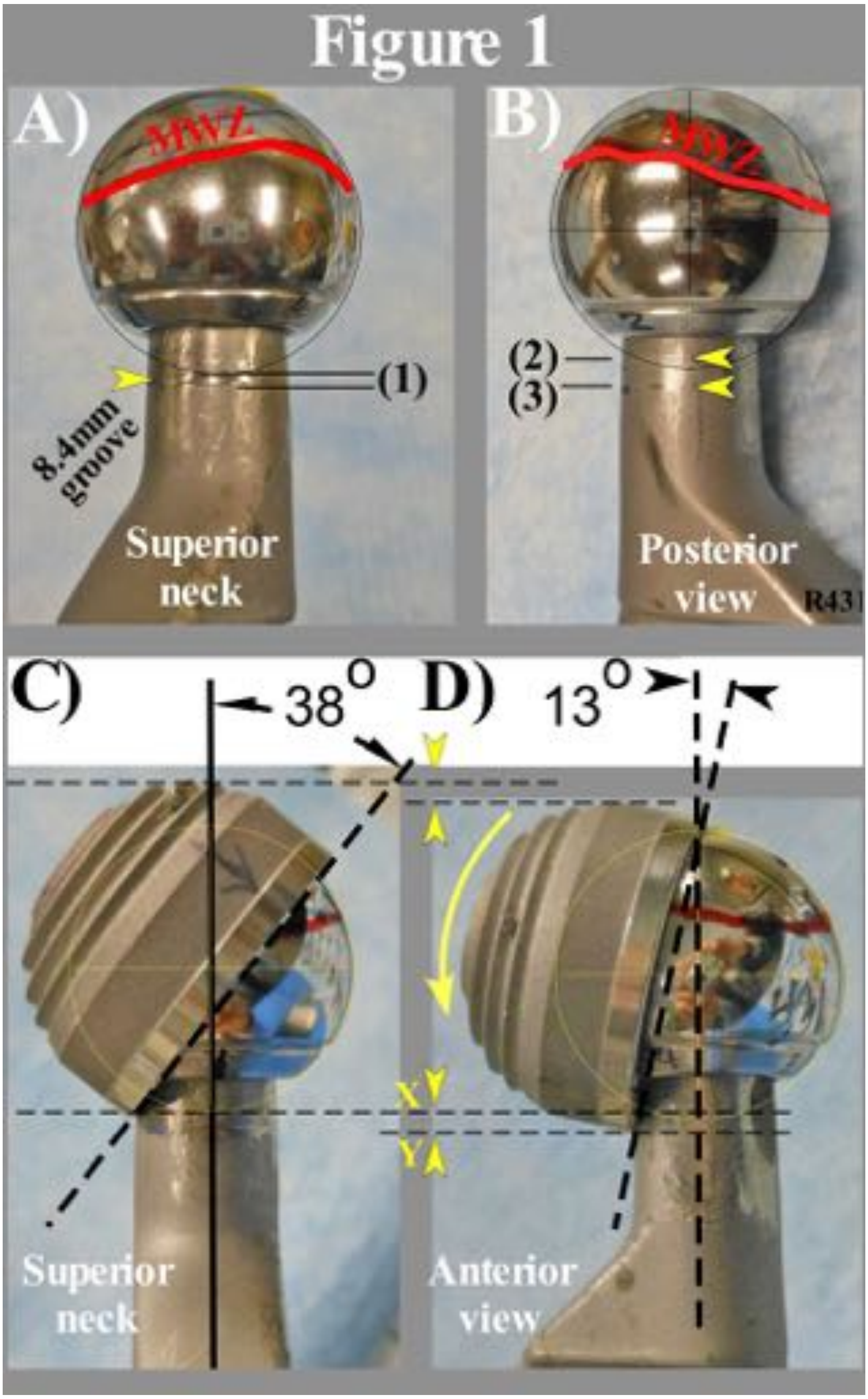

Figure 1

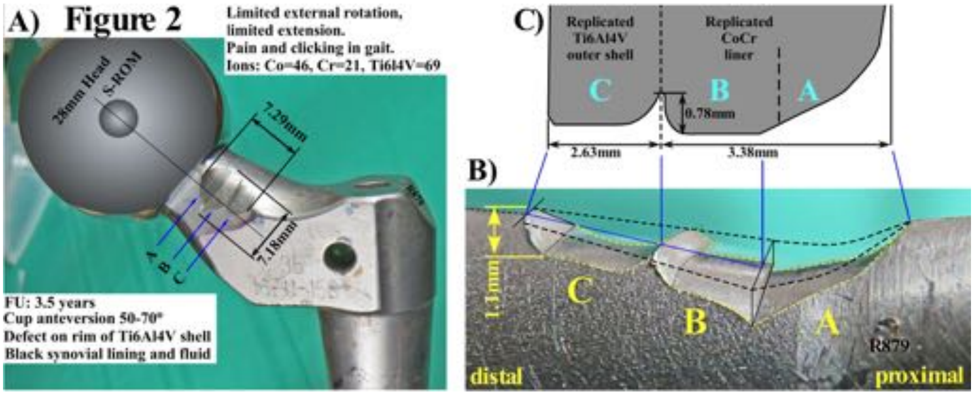

Figure 2

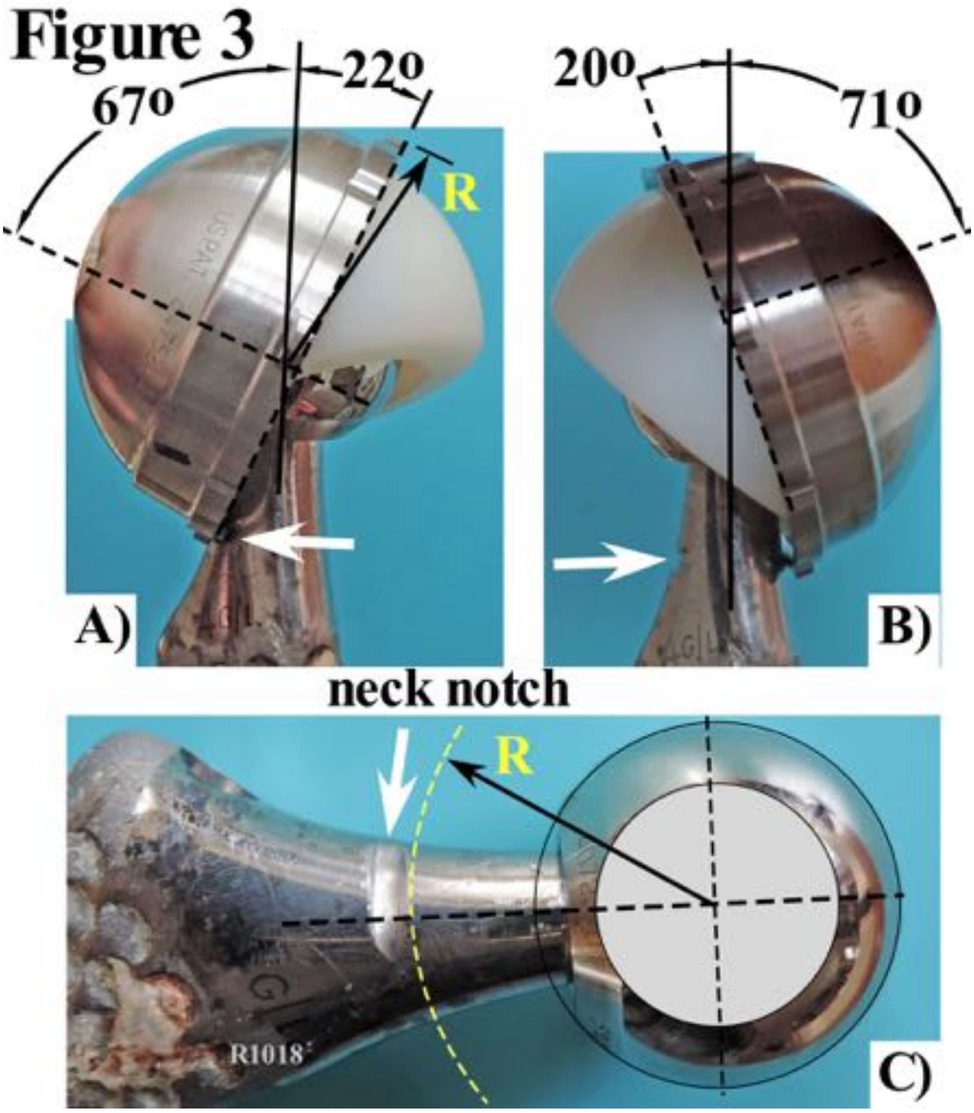

Figure 3

#6123

A Taper Impaction Technique to Eliminate Trunionnosis

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Taper corrosion and Trunionnosis are recognized as a major complication of hip replacement surgery presenting in a variety of clinical manifestations commonly referred to as Adverse Local Tissue Reactions. Metal debris is produced through Mechanically Assisted Crevice Corrosion with several implicating factors including mixed alloy components, taper design, head offset, femoral head size, and taper impaction techniques (including magnitude of force, control of alignment and environmental factors). Our project has focused singularly on taper impaction techniques and surgeon controlled factors, as we believe the process of head impaction unto a trunnion is non-standardized, which often times dooms the trunionn to failure. We have contemplated a standardization process, such that given the right tool, the surgeon can control the quality of the taper interlock, which may produce a "cold weld" or perfect taper interlock, eliminate micro motion, mechanically assisted crevice corrosion, and trunionnosis. We have considered four specific problems with current head to trunionn impaction techniques: 1. The magnitude of applied force is uncontrolled, haphazard, and non-standardized. 2. Non-axial application of force is the norm, which produces canting, leading to micro-motion and tribocorrosion. 3. The transfer of energy from the head to the trunionn interface is highly inefficient, such that the energy produced by the surgeon is mostly dissipated in a non-constrained system. 4. No in vitro studies exist to guide surgeons as to the magnitude of force required for a proper interlock.

Regardless of the design, including taper angles, larger heads, offset heads, mixed alloy components, shorter and slimmer trunionns there is a widespread problem with the process of head impaction onto the trunionn and the engagement of the modular taper interface that dooms the trunionn interface to failure. The deficiencies noted in current techniques are addressed with a simple tool and minor modification of the femoral stem. We present a new concept/apparatus for head to trunionn taper assembly that fully controls the magnitude and direction of assembly force within a constrained, dry and contaminant free environment. This tool allows application of a perfectly axial and high insertional forces without risk of damage to the femoral stem/bone interface to obtain a cold weld and perfect taper interlock with no chance for canting, micro motion and tribocorrosion. The concept has been verified through several prototypes and can be adopted in order to standardize the process of taper assembly, making this procedure independent of surgeon skill and strength, and minimizing the incidence of trunionnosis.

#5898

Fretting Initiated Crevice Corrosion of Stainless Steel on Stainless Steel

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Introduction:

Fretting crevice-corrosion (tribocorrosion) of metallic biomaterials is a major concern in orthopedic, spinal, dental and cardiovascular devices[1]. Stainless steel (i.e., 316L SS) is one alloy that sees extensive use in applications where fretting, crevices and corrosion may be present. While fretting-corrosion of this alloy has been somewhat studied, the concept of fretting-initiating crevice corrosion (FICC), where an initial fretting corrosion process leads to ongoing crevice-corrosion without continued fretting, is less understood. This study investigated the susceptibility of 316L SS to FICC and the role of applied potential on the process. The hypothesis is crevice-corrosion can be induced in 316L SS at potentials well below the pitting potential.

Materials and Methods:

A pin-on-disk fretting test system similar to that of Swaminathan et al.[2] was employed. Disks were ~35 mm in diameter and the pin area was ~500 mm. Samples were polished to 600 mm finish, cleaned with ethanol and distilled water. An Ag/AgCl wire as the reference, a carbon counter electrode and phosphate buffered saline (PBS, pH 7.4, Room T) were used for electrochemical testing. Load was controlled with a dead-weight system, monitored with a six-axis load cell (ATI Inc.). Interfacial motion was captured with a non-contact eddy current sensor (0.5 mm accuracy). Motion and load data acquisition was performed with Labview (National Instruments).

Samples were loaded to ~2 N. The potential per tests was increased from -250 to 250 mV (50 mV increments) with new locations and pins used in each repeat (n=3). Testing incorporated a 1 min rest before fretting (5 min, 1.25 Hz, 60 mm displacement saw tooth pattern). Fretting ceased and the load was held while currents were captured for another 5 min to assess ongoing crevice corrosion.

Results:

Testing showed that crevice corrosion can be initiated within minutes of fretting (or in a few cycles depending on potential; Fig. 1). Potentials as low as -100 mV showed evidence of corrosion, while sustained crevice corrosion was seen at -50 mV. As the potential increased above -50 mV, susceptibility to FICC increased. Fig. 2 is a typical cyclic polarization curve for 316L SS in PBS without fretting. Pitting starts at 400 mV vs Ag/AgCl, and the protection potential in this case is around potentials where FICC can be induced.

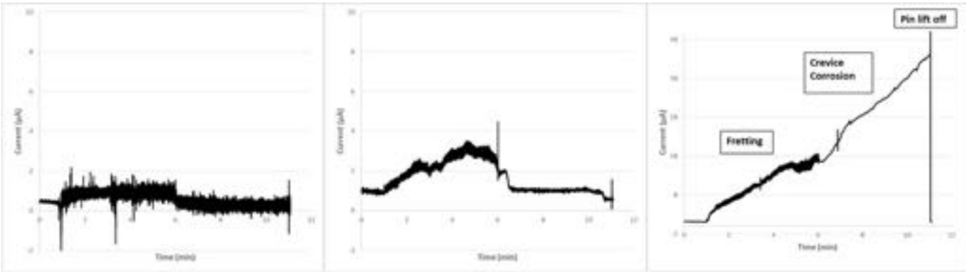
Discussion:

This study showed that 316L SS is prone to FICC starting at -100 mV and the severity of the crevice-corrosion damage depends on the applied potential (Fig. 3). Current after cessation of fretting takes longer to return to baseline or does not return indicating ongoing corrosion without fretting (Fig. 1). If the pin and disk are separated, the crevice-corrosion process stops immediately. The region immediately outside the fretting contact was crevice-like with a very small separation distance between the pin and disk surface which allowed crevice corrosion to develop (Fig. 3).

Conclusion:

316L SS can undergo FICC at potentials close to normal physiological electrode potential conditions. Few fretting cycles are required to develop conditions for continued crevice-corrosion. Higher potentials increased the susceptibility of FICC in 316L SS.

Figures



(a) (b) (c)

Fig. 1: The current vs. time behavior for fretted samples at (a) -50, (b) +50 & (c) +150 mV. Note the initial baseline recorded for 1 min then the rise of fretting current, followed by a 5 min hold where the current was monitored. (a) The currents immediately return to baseline when fretting is ceased. (b) The currents slowly recover back to baseline (~1 min recovery time). (c) After fretting the currents do not return to baseline and exhibit runaway current.

Figure 1

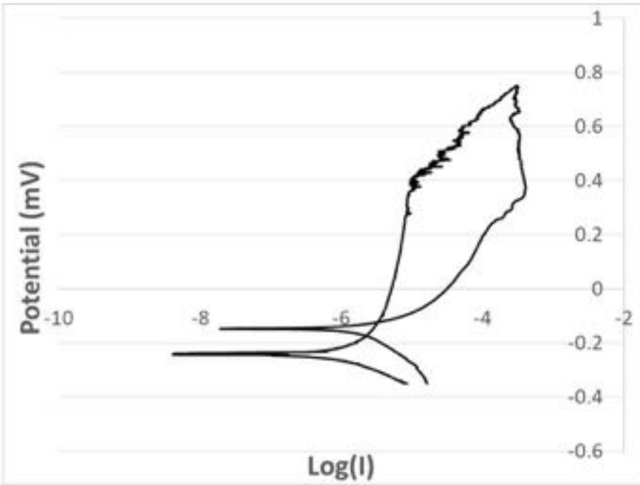
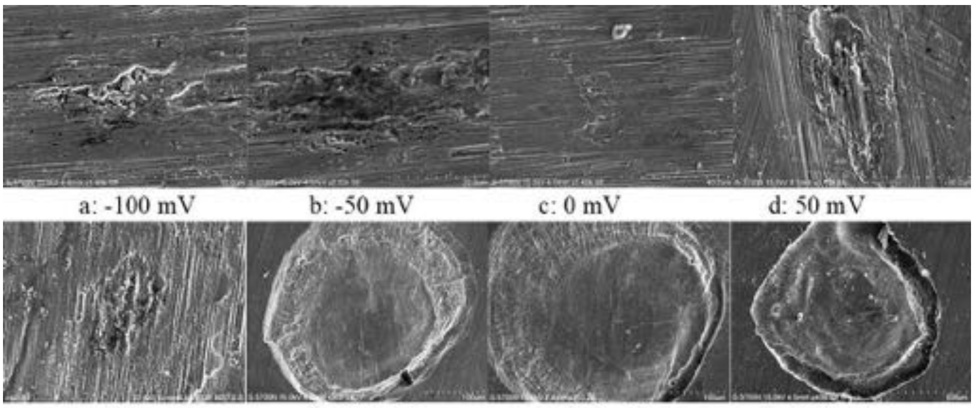


Fig 2: Characteristic plot of the potential vs. log current for a cyclic polarization test with the SS disk. Note the increase in current as the potential decreases and the low protection potential.

Figure 2



a: -100 mV b: -50 mV c: 0 mV d: 50 mV

e: 100 mV f: 150 mV g: 200 mV h: 250 mV

Fig. 3: Examples of fretting crevice corrosion damage in 316L SS after testing. Pitting damage seen in as low as -100 mV. More severe damage seen as potential is increased.

Figure 3

References: 1. Gilbert et al. ASM Handbook 2006; 13:826-36 2. Swaminathan et al. Biomaterials 2012; 33(22):5487-503

Figure 4

#6093

Gravimetric and CMM Validation of Wear in Edge-Loaded MOM Cups - a 10-Million Cycle Simulator Study Using Inverted-Cup Test Mode

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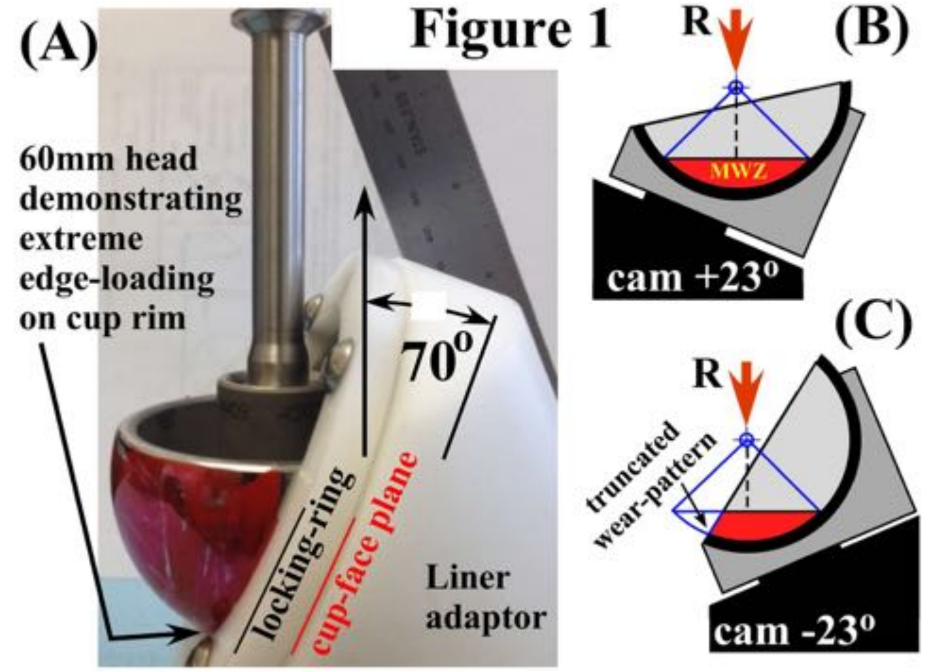
Clinical studies of metal-metal (MOM) bearings attributed adverse wear to cup “edge-loading” concepts. However, supporting scientific data remains scant. Simulator studies in Anatomic test mode with steeply-inclined cups showed MOM wear-rates elevated (Williams2008; Angadji2009), but still in normal range (< 2mm^3 per million cycles). Given the importance of this emergent edge-loading risk, we developed a new test method to study effects of steeply-inclined cups. The acetabular cups were mounted below the femoral head to permit a 70° extreme inclination that declined to a safe 24° inclination during each load cycle. Objectives were to determine (i) biphasic wear trending to 10-million cycles duration (10Mc), (ii), compare head and cup wear-rates, (iii) evaluate wear-patterns in heads and cups, and (iv) validate rim edge-loading occurred.

60mm MOM bearings were selected on the basis of prior hip-simulator study (Bowsher2009). Using Inverted test mode, cups were inclined at 47° to the plane of the orbiting cam (Fig. 1B) such that net inclination ranged 27^o (Fig. 1B) to 70^o (Figs. 1A, C) during each cycle. The 1st load peak was phased to peak cup-inclination. Test methods were similar to previous study in Anatomic test mode (Bowsher2009). At 10Mc duration, CMM analysis detailed the depths and patterns of worn areas.

Wear-volume in 60mm heads averaged 4.3mm^3 at 10Mc duration,with visualwear sketches showing narrow elliptical wear-patterns (Figs. 2A, B). The wear volume in three cups was 3-fold higher at 12.8mm^3, all visually demonstrating edge-loading (Fig. 2C). Note wear in 4th cup virtually doubled as outlier at 25.5mm^3. CMM analysis of low-wear in heads was somewhat confounded by protein contaminants. However, head#4 pattern spanning 113^o with 1656mm^2 area (Fig. 3A) showed good comparison to visual wear patterns (Figs. 2A, B). CMM revealed average head wear of only 7mm (+/- 25%). CMM views of truncated wear-patterns in cups (Figs. 3B, D) showed maximum wear depth at cup rims, 10.5mm in cup-4 and 26.3mm in outlier cup-1 (Figs. 3B, D). CMM demonstrated truncated cup wear-patterns, corresponding with visual wear patterns Figs. 2A, B), these descending 49-54^o below cup rims, with areas averaging 2192mm^2 (+/-20%).

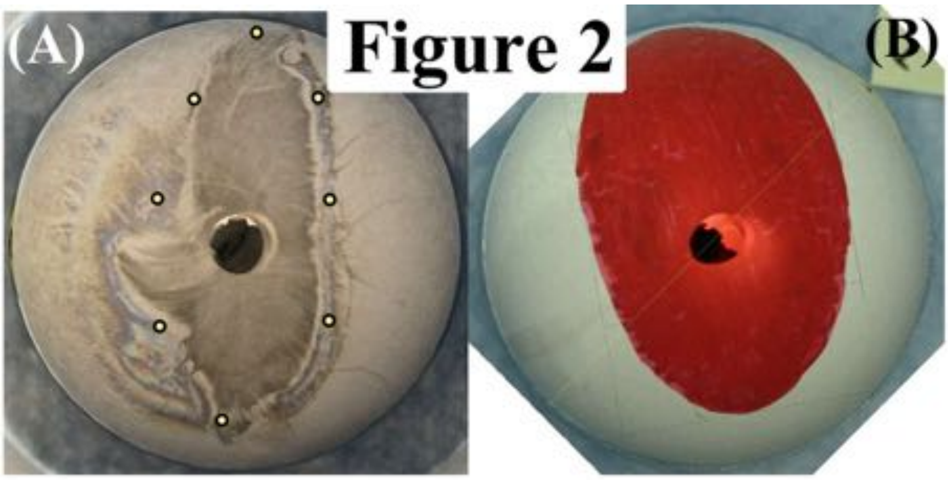
This MOM study introduced several novel concepts, (a) cup inclinations varying dynamically with Inverted test mode, (b) 60mm cups, (c) 70^o peak inclination, (d) 10-million cycle duration and (e) analysis of edge-loading conditions. Regardless, the resulting wear with edge-loaded cups did not match the adverse clinical results. One possibility was that this test did not simulate true edge-loading. Importantly, CMM studies verified that cups had the truncated wear-patterns typical of edge-loading and also confirmed that maximum wear depth occurred at cup rims (Figs. 3B, D). Moreover, cup-1 had the greatest rim wear of 26.3mm compared to three cups averaging 15mm. This x1.7-fold difference in CMM wear depth corresponded well with the x2-fold difference in gravimetric wear (cup-1 = 25.5mm^3 vs 3 cup-avg. = 12.8mm^3). In conclusion, the gravimetric data demonstrated biphasic MOM wear trends to 10-million cycles duration and CMM analysis confirmed that the edge-loading conditions had been satisfied in this novel study.

Figures



A) Inverted-cup fixture showing rim-loading (70°)
B) Cup in safe zone, at minimum inclination = 27°
C) Cup edge-loaded, at maximum inclination = 70°

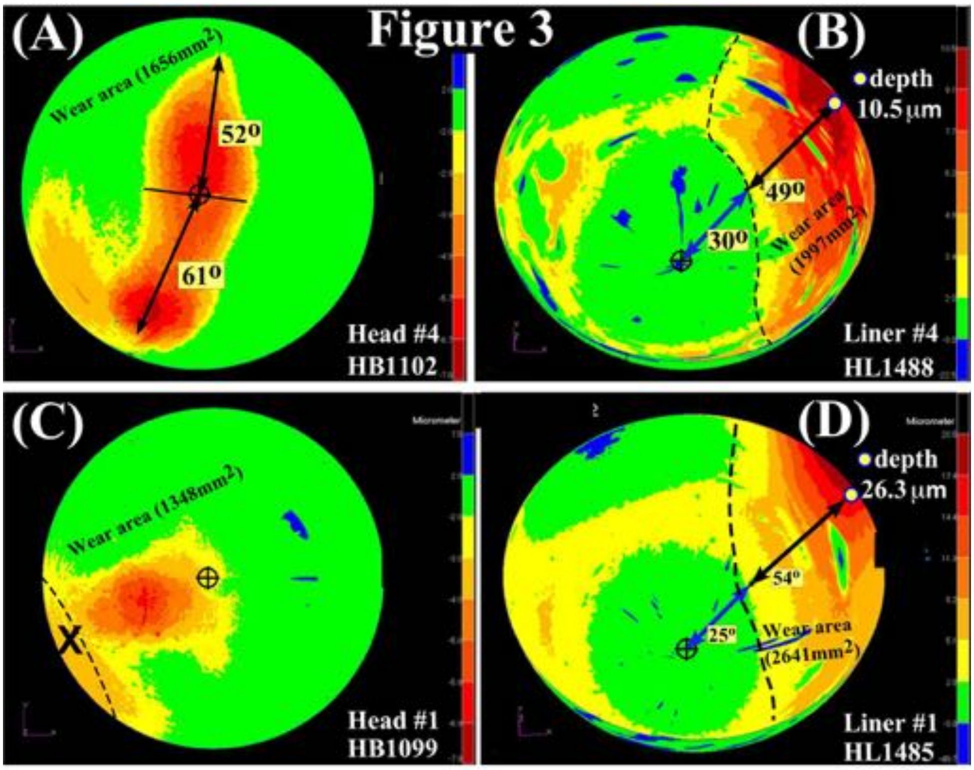
Figure 1



A) Wear-scar boundary on head showing coating of degraded proteins
B) Site of head wear-scar painted red for photography

C) Sites of cup wear-scars (MWZ) painted red for photography

Figure 2



A) CMM shows head-4 wear-pattern as 113° ellongated ellipse, wear depth 7.6µm
B) CMM shows cup-4 wear-pattern truncation at rim (49°), wear depth 10.5µm at rim
C) CMM shows minimal head-1 wear-pattern, shallow depth obscured by proteins
D) CMM shows cup-1 wear-pattern truncation at rim (54°), wear depth 26.3µm at rim

Figure 3

Acknowledgements
This study was funded partially by funding from FDA-1090372 and Arthroplasty for Arthritis Foundation (UK-1051165).

Figure 4

#6195

The Wear of Poly-Ether-Ether-Ketone (PEEK) Based Bearing Couples Subject to Different Lubricant Protein Concentrations Under Kinematics Relevant to Total Knee Replacements

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Osteolysis, a direct consequence of polyethylene (PE) wear debris, leading to aseptic loosening remains the major reason, 33 %, for knee revision surgeries [1]. Poly-ether-ether-ketone (PEEK), is currently used as an all-polymer cervical disc replacement (NuNec), and has potential as an alternative biomaterial. For a new bearing couple to be considered it is important that the wear, under adverse conditions, be examined.The aim of this project was to investigate the wear produced from PEEK-on-PEEK, PEEK-on-PE and PE-on-PEEK bearing couples under different lubricant protein concentrations.

Injection moulded PEEK and GUR-1020 ultra-high-molecular-weight-polyethylene (UHMWPE) pins articulated on either injection moulded PEEK or GUR-1020 UHMWPE plates in a four station multi-directional motion pin-on-plate test rig. Tests were ran to one million cycles with both reciprocation and rotation set at one hertz, a 20 mm sliding distance and applied contact pressure of 5.6 MPa. Different protein concentrations of newborn calf serum (BCS) was used as the lubricant 1.28, 21 and 64 mg/mL, (2, 33 and 100 % respectively). Wear was assessed gravimetrically, every 250,000 cycles, with soak controls to account for lubricant uptake, and the lubricant changed. Statistical analysis was by ANOVA with Tukey post hoc test (minitab) with significance taken when $p< 0.05$.

The combined pin and plate wear factors are shown in *Figure 1*. Visible wear scars were evident on the PEEK plates from PEEK-on-PEEK tests, and protein precipitation in the lubricant was visibly noted for all bearing couples when tested at 100 % BCS. The PEEK-on-PEEK, higher friction, bearing couple had the higher wear across all three protein concentrations, with a statistically significant (ANOVA, $P<0.05$) decrease in wear factor with increase in protein concentration. This is in contrast to both the PEEK-on-PE and PE-on-PEEK bearing couples where there was an increase in wear from 2 – 33 % BCS followed by a decrease with a further increase of proteins to 100 % however, no difference was statistically significant. A similar trend to that noted by Cowie *et al* for UHMWPE-on-PEEK [2].

These results suggest that proteins present in the test lubricants have a significant effect on the wear of PEEK self-mating bearing couples. The increased wear factor of the PEEK-on-PEEK bearing couple could be due to the material types and protein adsorption. At 2 % BCS there are not a sufficient amount of proteins in the lubricant to adhere to the surface forming a protective boundary layer. However, it should be noted that due to the high friction bearing couples, frictional heat may have been generated from the continuous running of the test, increasing the rate of protein degradation potentially decreasing the wear, a test artefact which may not be present *in-vivo.*

As the protein concentration of periprosthetic synovial fluid differs from healthy synovial fluid, ranging between 15 – 55 mg/ml [3], these results show promise for PE-on-PEEK as an alternative material combination to the current PE-on-Metal implants, reducing the risk of metal hypersensitivity in patients. To further assess PEEK bearing safety analysis of the wear debris produced is required.

Figures

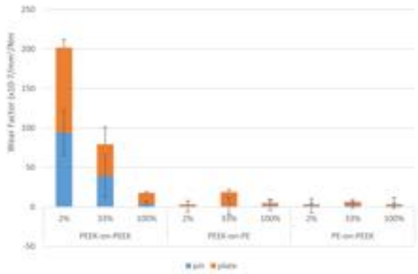

Figure 1: Wear factors (x10^{-7}) mm^3/Nm for PEEK-on-PEEK, PEEK-on-PE and PE-on-PEEK pin-on-plate bearing couples in 2, 33 and 100 % bovine calf serum lubricant. Error bars represent standard deviation.

Figure 1

#5531

In Vivo Polyethylene Wear Measurement of a Contemporary Total Knee Arthroplasty Implant: A Minimum 10 Year Follow-Up

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Background: Measuring in vivo wear of modern, wear resistant knee replacement implants is technically challenging but has been described using radiostereometric analysis (RSA). Such measurements would enable analysis of how patient and surgical factors influence wear in well performing knees.

Methods: Forty-nine patients with a minimum follow-up of 10 years were recruited. All patients had a single posterior stabilized, cobalt-chromium on conventional polyethylene implant system. Patients underwent incremental standing RSA exams from 0° to 120° of flexion. Linear and volumetric wear rates were measured. Wear was compared between patients based on demographics, implant size, and alignment, and was reported as median and interquartile range (IQR).

Results: The linear wear rate laterally was 0.047 mm/year (IQR 0.034-0.066 mm/year) and medially was 0.052 mm/year (IQR 0.040-0.069 mm/year). The volumetric wear rate laterally was 10.7 mm^3/year (IQR 4.8-16.3 mm^3/year) and medially was 13.4 mm^3/year (IQR 6.5-20.4 mm^3/year). The volumetric wear rate of the post was 4.3 mm^3/year (IQR 2.1-6.7 mm^3/year). Volumetric wear rate was greater in male patients ($p < 0.0001$), patients with height ≥170 cm ($p = 0.0001$), and larger tibial inserts ($p < 0.01$). Volumetric wear rate was not different between patients with neutral or varus limb alignment ($p = 0.72$).

Conclusion: The implant in this study demonstrates excellent wear resistance in patients with well performing knee replacements at long-term follow-up, with wear magnitudes in agreement to reported values from retrieval studies. Patient sex and height and tibial insert size affected wear rates, but age, weight, BMI, tibial insert thickness, and alignment did not.

#5845

Start-Up Friction Testing for Evaluating Tribological Performance of Cartilage

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Introduction

The standing still position may increase the solid contact area at the sliding surface of the regenerated cartilage and may drastically increases the wear-like destruction. Motion from stationary loading, such as standing work, golf and so on, has a possibility to increase molecule scission at the sliding surface. However, the start–up friction and wear-like destruction of regenerated cartilage is difficult to examine quantitatively using the position-controlled pin-on-plate type friction tester. In this study, several static friction testers were prepared to measure parameters including Destruction Energy Index (DEI) which is a theoretical index for evaluating destruction at sliding interface by minimizing the effect of viscosity.

Materials and Methods

[1] Start-up friction measurement using inclined plane friction tester

The start-up friction coefficient was measured by the inclination of an object[1)]. The outline of the inclined plane tester is shown in Fig. 1, where the inclination of the plane is increased at rates of 0.072, 0.14, 0.36, 0.72 degrees per second by an electric motor until the test block begins to slide.

[2] DEI measurement using tension-type friction tester

A static friction tester with a laser displacement meter to measure the micro displacement was made[2)]. Outline of the tester is shown in Fig. 2, where specimen was set on the stand fixing the specimen with weight, and a prism was used as the friction counterpart. The stand fixing the specimen is pulled at a constant speed through the spring, and the test is terminated when the sample starts to slide. At this time, the start-up friction and the micro displacement up to starting point are calculated from load and displacement measured by the load cell and the laser displacement meter.

Results and Discussions

Fig. 3 shows load increase rate - start-up friction coefficient diagram for cartilage against 2-methacryl-oyloxyethyl phosphoryl choline (MPC) polymer grafted surface[1,3)]. Linear relationships between the above two parameters were observed[1)]. We assumed a bristle model using irreversible viscoelasticity and the presence of micro displacement up to starting point[2)] to explain the results. This bristle has a deflection x_0 (micro displacement up to starting point), and the sum of the elastic element and the viscous element is observed as the friction force. The energy consumed by the viscous element does not directly relate to destruction. On the other hand, the elastic energy released from the system contributes to destruction phenomena like molecular scission, and we defined this energy as Destruction Energy Index (DEI).

As DEI is expressed by the product of f_k (elastic component of start-up friction) and half value of x_0 , tension type friction tester with a laser displacement meter to measure x_0 was designed.

References

[1] Negishi, T., Consideration of friction coefficient excluding viscosity resistance, Graduation Thesis, Kyoto University, 2016.

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[3] Morita, Y., Tomita, N., Aoki, H., Sonobe, M., Wakitani, S., Tamada, Y., Suguro, T. and Ikeuchi, K., Frictional Propertics of Regenerated Cartilage in Vitro, Jounal of Biomechanics, 39(1), 103-109 (2006).

Figures

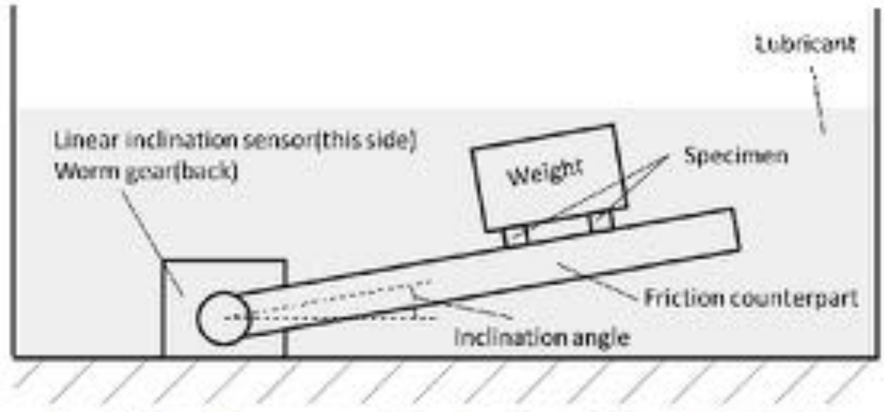
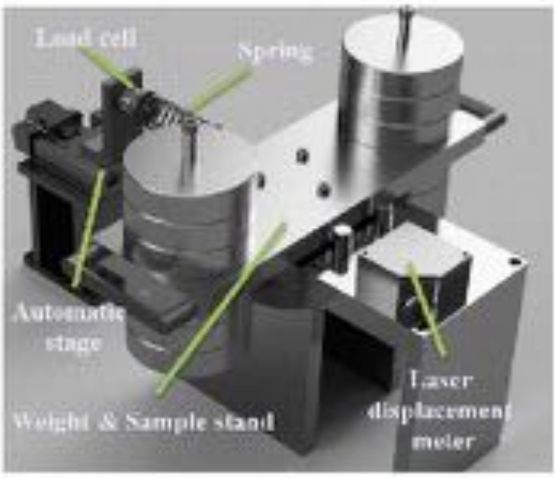
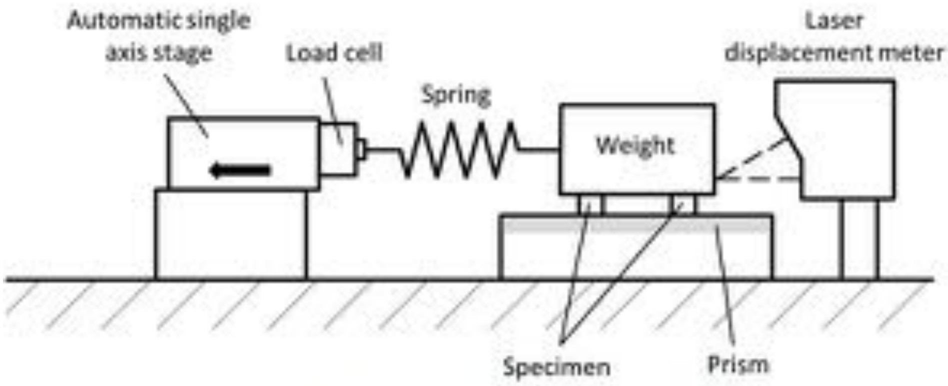


Fig. 1. Start-up friction measurement using pin-on-disc and inclined plane friction tester

Figure 1



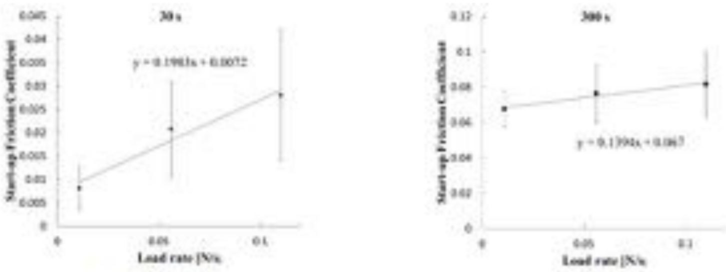
(a) Overall view of tension type friction tester



(b) Mechanism diagram of tension type friction tester

Fig. 2. DEI measurement using tension type friction tester

Figure 2



(a) Duration time：30 s

(b) Duration time：300 s

Fig. 3. Linear relationship between Load rate and Start-up Friction Coefficient. Data represent mean±SD (n=4or5).

(a)Duration time：30 s and (b)Duration time：300 s

Figure 3

#5835

Proposal of Destruction Energy Index for Evaluating Tribological Performance of Joint

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Introduction

Wear volume is one of the most important factors for evaluating tribological performance. However, the wear measurement is affected by several factors such as solid contact, adsorption and so on, and doesn't always correlate with friction force when viscoelastic bodies (such as Ultra High Molecule Weight Polyethylene) are in contact with viscous fluid[1]. Therefore, we considered that it is insufficient to consider only the friction force for tribological measurement. In this study, we focused on static friction of start-up friction, and assumed a bristle model using irreversible viscoelasticity and the presence of micro displacement before start-up[2]. This bristle has a deflection x_0 (micro displacement up to starting point), and the sum of the elastic element and the viscous element is observed as the friction force. k is the elastic modulus and λ is the viscosity of UHMWPE (Fig. 1). The energy consumed by the viscous element doesn't directly relate to destruction. Besides, the elastic energy released from the system contributes to destruction phenomena like abrasion and molecular scission, and we defined this energy as Destruction Energy Index (DEI). The DEI is expressed by the product of f_k (elastic component of starting frictional force) and half value of x_0.

Materials and Methods

A static friction tester with a laser displacement meter to measure the micro displacement was made. Three virgin UHMWPE cylinders with 5 mm diameter were pulled under 5.3 MPa surface pressure on bottom surfaces of trapezoidal prisms by six kinds of load increase rates, and start-up friction force and start-up displacement between UHMWPE and trapezoidal prisms were measured. We used silicone oil of different viscosities (10 centistokes [cSt], 100 cSt, 1000 cSt) as lubricating liquid (Fig. 2).

Results and Discussions

In this experiment, We assumed that DEI stays constant with different viscosity of lubricating liquid, and regarded displacement giving the most matching DEI by comparing with each viscosity as ultimate x_0. There is a positive correlation between the load increase rate[3] and the start-up friction force and it is possible to extract f_k by extrapolating the load increase rate to zero[4]. Degree of dispersion of DEI in three kinds of viscosity at each x_0 was compared by using the Coefficient of Variation, and the ultimate x_0 assumed to be the minimum value of the Coefficient of Variation (Fig. 3). In this particular case, the DEI was 17.48μJ and the ultimate x_0 was calculated as 3μm.

DEI is a theoretical index for evaluating destruction at sliding interface by minimizing the effect of viscosity. Relationship between DEI and inner destructions such as wear and molecule scission in the fluid has not been proved in the joint.

References

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[4] Mikami S., Estimation of Destruction Energy Index in start-up friction and consideration of error factor, 2018

Figures

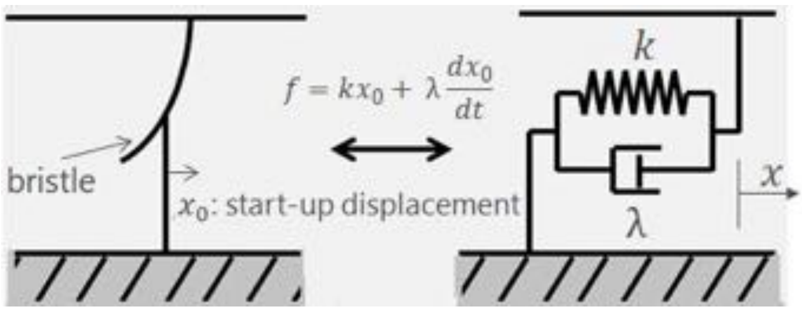

Figure 1

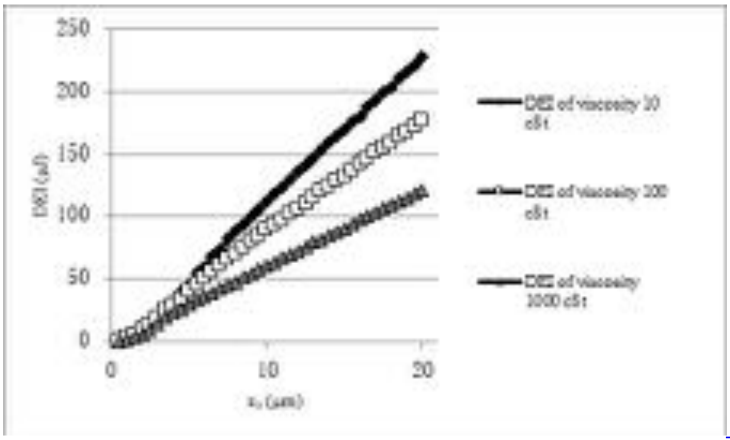

Figure 2

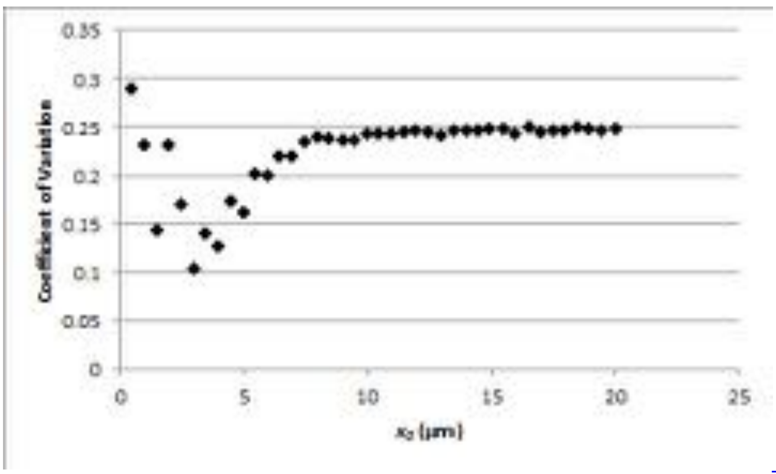

Figure 3

#5746

Destruction Energy Index (DEI) of Vitamin E-Blended UHMWPE

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Introduction

Ultrahigh molecular weight polyethylene (UHMWPE) containing vitamin E (dl-a-Tocopherol) has been developed to use as a bearing surface for total joint replacement. The vitamin E added UHMWPE was reported to prevent crack initiation at subsurface grain boundaries of UHMWPE, and the wear volume examined by knee joint simulator was reduced to 30 % lower than that of virgin UHMWPE [1]. On the other hand, Okubo et al evaluated the tribological performance of the vitamin E-blended UHMWPE, and reported that the friction force was higher than that of virgin UHMWPE [2]. In this study, Destruction Energy Index(DEI) is a tribological index for evaluating viscoelastic destruction at sliding interface. DEI of two different types of UHMWPE (virgin UHMWPE, vitamin E-blended UHMWPE) was evaluated and the effect of the vitamin E-blending was discussed.

Materials and Methods

The DEI is expressed by the product of f_k (an elastic component of starting friction force) and a half value of x_0 (micro displacement up to starting point). The start-up friction force is correlated with the load increase rate [3]. And we estimated f_k by extrapolating load increase rates to zero for start-up friction force [4]. To measure these parameters, the static friction tester with load cell and laser displacement sensor was made, as shown in Fig.1. The specimens geometry was a flat-ended cylindrical shape(φ5) and the nominal contact stress on the surface was 5.3 MPa. The measurements of the each UHMWPE were carried out against the prisms, in the lubricant of silicone oil of different viscosities (10 cSt, 100 cSt, 1000 cSt) .

Results and Discussions

The DEI was calculated by changing x_0 in unit of 0.5 µm for the virgin UHMWPE and VE-UHMWPE, as shown in Fig2. As the DEI is assumed to be a constant against any viscosity of the lubricant, we derived the degree of dispersion by using the Coefficient of Variation, as shown in Fig3. In this assumption, ultimate x_0 represent the minimum value of the Coefficient of Variation. The DEI and the ultimate x_0 of the VE-UHMWPE were lower than those of the virgin UHMWPE. Coefficient of Variation of the VE-UHMWPE was higher than that one of the virgin UHMWPE.

DEI is a tribological index for evaluating destruction at sliding interface by minimizing the effect of viscosity. In the present experiment, silicone oil was used as lubricating liquid where molecule scission in the liquid thought to be negligible. It is suggested that viscosity term of sliding interface is increased and the destruction is reduced by blending vitamin E to UHMWPE.

References

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Figures

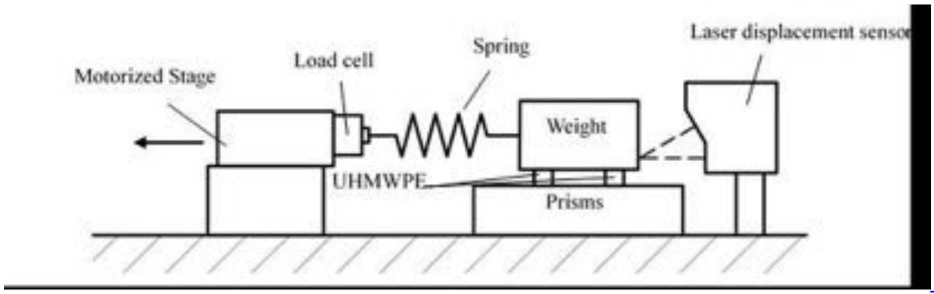

Figure 1

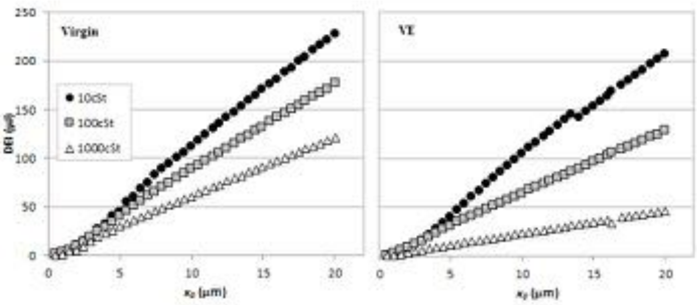

Figure 2

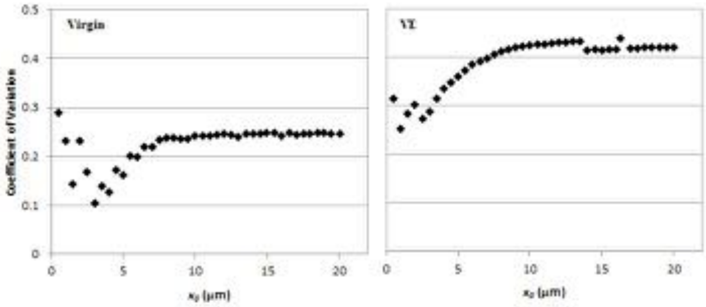
Virgin
YE
Coefficient of Variation
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
x_0 (µm)
x_0 (µm)

Figure 3

#5727

Wear and Deformation of Metal-on-Polyethylene Bearings Under Edge Loading Conditions: A Cross-Laboratory Study

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Introduction and Aims

Retrieval studies of total hip replacements have shown evidence of cup (liner) edge loading[1]. Observations of separation between heads and cups during gait up to 2mm have also been recorded using flouroscopy[2]. The severity of edge loading, deformation and wear driven by translational mismatch between centres of rotation of the femoral head and acetabular liner during gait[3] has been shown to increase with increases in cup inclination angle and increases in medial–lateral offset deficiency. It is now important to consider edge loading when assessing the mechanical and tribological performance of hip replacement bearings. It is necessary to modify hip simulators in the laboratory to replicate edge loading driven by dynamic separation. Different approaches are being taken in different laboratories with different simulators. The aim of this study was to evaluate deformation and wear of polyethylene liners under edge loading conditions tested in three different laboratories.

Methods

Three hip simulators were used to test identical 36mm diameter metal-on-polyethylene hip implants (DePuy Synthes Joint Reconstruction, Leeds, UK). Simulators used were: (1) EM13 ProSim, University of Leeds (Leeds, UK); (2) EM ProSim, DePuy Synthes (Leeds, UK); and (3) AMTI, DePuy Synthes (Warsaw, IN, USA). A gait cycle was applied consisting of three axes of rotation conditions (ISO14242-1). Load and kinematics for both simulator types are illustrated in Figure 1.

Tests were run under standard walking conditions (ISO14242-1) and edge loading conditions. On ProSim simulators, edge loading was achieved by applying a 4mm mismatch between the centres of rotation of the femoral head and acetabular liner. On the AMTI simulator, edge loading was achieved by applying a 2mm pre-determined separation[4]. Under edge loading conditions, the acetabular liner was positioned at an inclination angle equivalent to 65° in vivo. Lubricant was diluted new-born calf serum (25% v/v). Wear measurements were assessed gravimetrically and undertaken at 0.5 and/or 1.0 million cycle intervals thereafter per ISO 14242-2. Deformation of the liner was determined using a coordinate measurement machine and RedLux nano optical profiler. Mean wear rates were calculated (±95% Confidence Limits) and statistical analysis was carried out using t-tests with a significance level taken at $p<0.05$.

Results

Dynamic separation measured on the ProSim equipment was 2.4mm, similar to the pre-determined separation value set at the DePuy Warsaw site (2mm). The addition of edge loading to the gait cycle significantly increased ($p\leq0.01$) wear rates of polyethylene by 44% (1), 36% (2) and 45% (3), Figure 2. Edge loading resulted in deformation between 200 and 300µm at the rim of the polyethylene liners after testing at all sites, Figure 3.

Conclusions

Edge loading driven by separation was replicated at three different sites, leading to similar levels of increased wear and deformation at the rim of the polyethylene liner.

This comparative work demonstrates an effective method towards reaching a wider consensus for standardisation of testing conditions for MoP hip replacement bearings under adverse edge loading conditions.

[1] Tower et al., 2007. [2] Komistek et.al. 2002. [3] Ali et al., 2017. [4] Hippensteel et al., 2017.

Figures

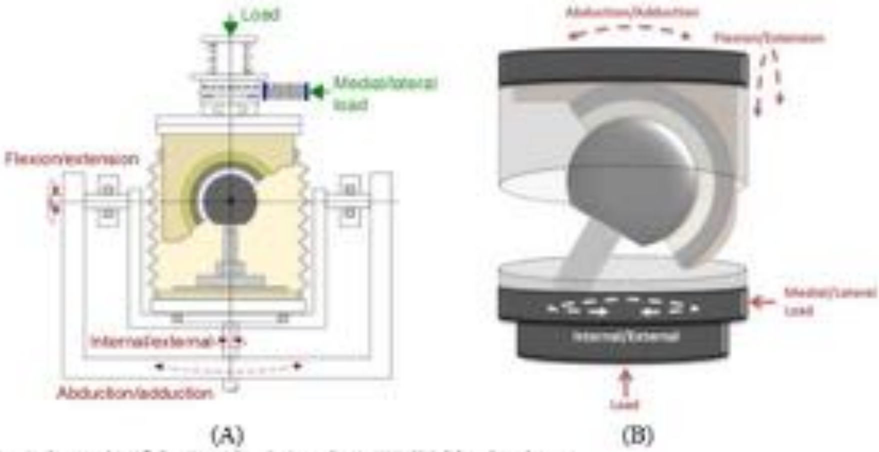

Figure 1. Schematic of the ProSim (A) and AMTI (B) hip simulators

[Figure 1](#)

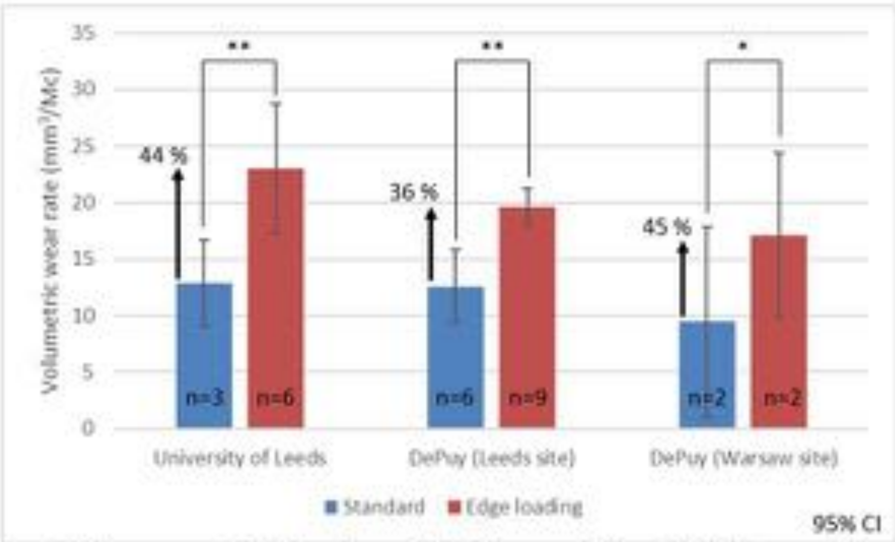

Figure 2. Mean wear rate for a 36mm diameter MoP under a standard and edge loading test for three sites, the University of Leeds, DePuy Synthes (Leeds site) and DePuy Synthes (Warsaw site).
Notes; * = $p<0.05$ and ** = $p<0.01$

[Figure 2](#)

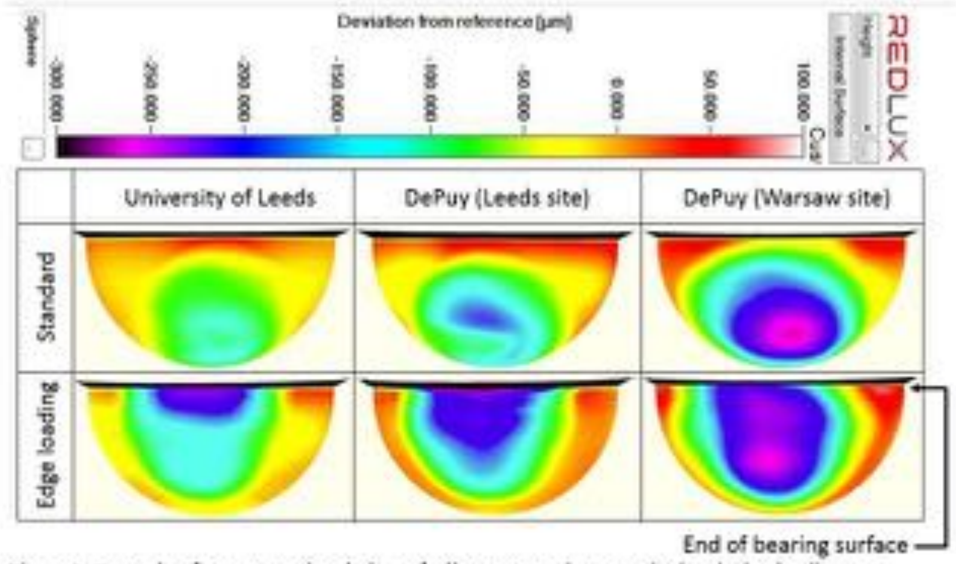

Figure 3. Example of a cross-sectional view of a liner scan under a standard and edge loading test conditions for three sites, the University of Leeds, DePuy Synthes (Leeds site) and DePuy Synthes (Warsaw site). The reference value of zero is the sample radius and a negative deviation is the indication of the wear and deformation of the sample.

Figure 3

#6185

Effectiveness of Theoretical/Empirical Relationship in Predicting Polyethylene Wear

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Objective: Clinical wear depends on several factors such as implant specific factors (material, design, and sterilization), surgical factors/techniques, and patient-specific factors (weights and activities). The load magnitude for wear testing in the standard protocols (i.e., 2 kN as per ASTM F1714 or 3 kN as per ISO 14243-3) represent an average patient weight and does not address the other “what-if’” scenarios (i.e., wear vs. patient weights, activities, duration, etc.,). The results from *in- vitro* testing report the data in wear (mg) or wear rate (mg/Mc) and are only applicable to the parameters (i.e., loads, bearing diameter, thickness, etc.,) used for the testing and not suitable to the variations seen in clinical scenarios. Therefore, it is essential to present the wear summary that can normalize the parameters and which is relevant in both *in-vitro* and *in-vivo* conditions. The goal of the current study is an attempt to present wear as a parameter (i.e., wear factor that combines the wear test data and established-theoretical relationship) and is thus applicable in both *in-vivo* and *in-vitro* scenarios.

Methods: Wear factor was first evaluated using actual wear testing conducted on metal on cross-linked polyethylene bearings along with well-established Dowson’s wall bridge equation.

As per Dowson-Wallbridge, volumetric wear is

V=2.376â˘™KNWR+C or K=V/(2.376â˘™NWR)

where V is the volumetric wear in mm^3, K is the wear factor in mm^3/Nmm, N is the number of cycles, W is the load in Newtons, R is the bearing radius in mm, and C is the creep (assumed to be negligible, i.e., C=0 in this model.

28 mm simulator wear was first used to evaluate wear factor, but since simulator wear presented as a mass loss, these results were converted to volumetric wear using the equation

$V=m/\rho$,

(m is the wear in mg and r is the density of XLPE in mg/mm^3 (=0.923).

The Dowson-Wallbridge equation was then validated for predictive accuracy against actual wear testing on the predecessor THR system. The wear factor thus obtained was used to compute the theoretical-wear for other sizes (i.e., 42 and 46 mm bearings). The theoretical-wear was then compared to simulator wear for predictive accuracy.

Results & Discussion: Figure1 below shows the verification of the predictive capability of the Dowson-Wallbridge equation against historical wear data. The theoretical-wear (for 42 and 46 mm bearings) evaluated using wear factor was in good agreement with the simulator wear The results show Dowson’s Wallbridge equation was verified and thus can be used to assess the wear factor. The results show that the wear factor for XLPE system is 1.79×10^{-10} mm^3/N-mm. Elfick et al. evaluated the clinical wear factor for 47 retrieved acetabular components with varying diameters, patients, and liner thickness ranging from 1.8 mm (thinnest) to 11.0 mm thick liners using the Dowson-Wallbridge equation and reported the mean wear factor as 1.93×10^{-9} mm^3/N-m. The results of the current evaluation are also in good agreement with clinical studies.

Figures

Size	Simulator Wear (mg)	Vol Wear (mm^3)	N (Cycles)	W (N)	OBM-Sliding Distance (mm)	K (mm^3/Nmm)	Theoretical Wear (mm^3)	% Difference
28	24.83	26.70	5000000	2000	29.26	9.12472E-11	NA	NA
42	35.94	38.65	5000000	2000	43.89	9.12472E-11	40.05	4%
46	42.92	46.15	5000000	2000	48.07	9.12472E-11	43.86	-5%

Figure 1: Evaluation of Wear Factor-verification of the predictive capability of the Dowson-Wallbridge equation against historical wear data

Figure 1

Friction Factor and Wear Determinations of Metal-on-Polyethylene Hip Implants Using an Anatomical Motion Hip Simulator.

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Introduction and Aims

A recent submission to ASTM, WK28778 entitled "Standard test method for determination of friction torque and friction factor for hip implants using an anatomical motion hip simulator"[1], describes a proposal for determining the friction factor of hip implant devices. Determination of a friction factor in an implant bearing couple using a full kinematic walking cycle as described in ISO14242-1 may offer designers and engineers valuable input to improve wear characteristics, minimize torque and improve long term performance of hip implants. The aim of this study was to investigate differences in friction factors between two commercially available polyethylene materials using the procedure proposed.

Methods

Two polyethylene acetabular liner material test groups were chosen for this study: commercially available (A) Marathon® and (B) AltrX®. All liners were machined to current production specifications with an inner diameter of 36mm and an outer diameter of 56mm. Roughness (Ra) of the liners was measured using contact profilometry and was undertaken in the head-liner contact area before and after wear testing (Table 1). Liners were soaked in bovine serum for 48 hours prior to testing. Friction factor measurements were taken per ASTM WK28778 prior to and after wear testing using an external six degrees of freedom load cell (ATI Industrial Automation) and a reduced maximum vertical load of 1900N (Figure 1). Friction factor and wear testing was conducted in bovine serum (18mg/mL total protein concentration) supplemented with 0.056% sodium azide (preservative) and 5.56mM EDTA (calcium stabilizer) on a 12-station AMTI (Watertown, MA) ADL hip simulator with load soak controls per ISO 14242-1:2014(E). The liners were removed from the machine, cleaned and gravimetric wear determined per ISO 14242-2:2000(E) every 0.5 million cycles (MCyc) through 3Mcyc to evaluate wear.

Results

The average wear rates, calculated friction factors and liner roughness values, both pre and post 3Mcyc wear testing, are presented in Table 1. It is observed that although the measured wear rates were significantly different between the test groups, the measured friction factors were not significantly different between groups. Figure 2 shows the friction factor measured in the region of highest interest, from heel strike through toe off of the gait cycle (the 1st 60% of the kinematics cycle described in ISO 14242). Data gathered outside this region, where compressive force is less than 1400N is omitted from the calculations as the reduced load results in low and noisy data[2]. It is observed that the resultant friction curves for untested bearing couples have a larger spread across the 4 measured samples than those following 3Mcyc of standard wear, most likely due to variations in polyethylene roughness, contact area and clearances between the bearing couples.

Conclusions

It is concluded from this study that the draft ASTM protocol proposed is capable of measuring frictional effects in MoP hip bearing couples, and for the polyethylene materials tested herein there is no significant difference between the measured friction factors when all other parameters (i.e. design and gait cycle) are controlled.

[1] ASTM WK28778. [2] Haider *et al.,* 2016.

Figures

Figure 1: Representative test set-up used for friction testing incorporating the external ATI 6 degree of freedom load cell and the closed loop serum recirculation system (a). The relative machine motions used for wear and frictional torque are shown in (b) courtesy of Haider *et.al.*[2]

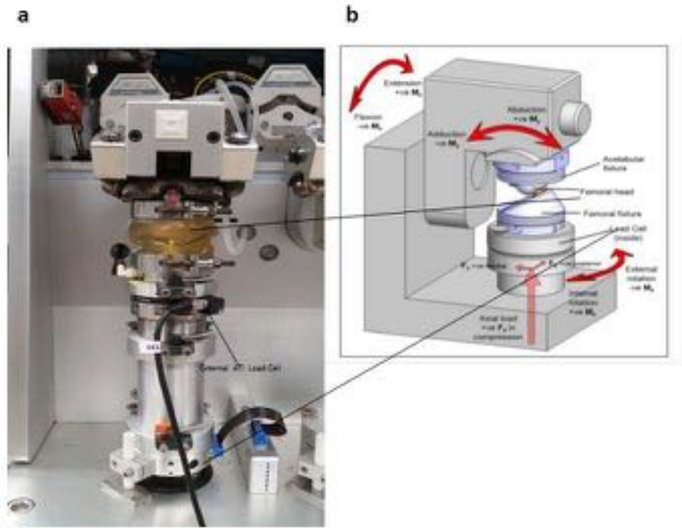

Figure 1

Figure 2: Friction factor measured from heel strike through toe off (1st 60% of the ISO 14242 gait cycle) for polymer groups pre and post wear testing (3Mcyc)

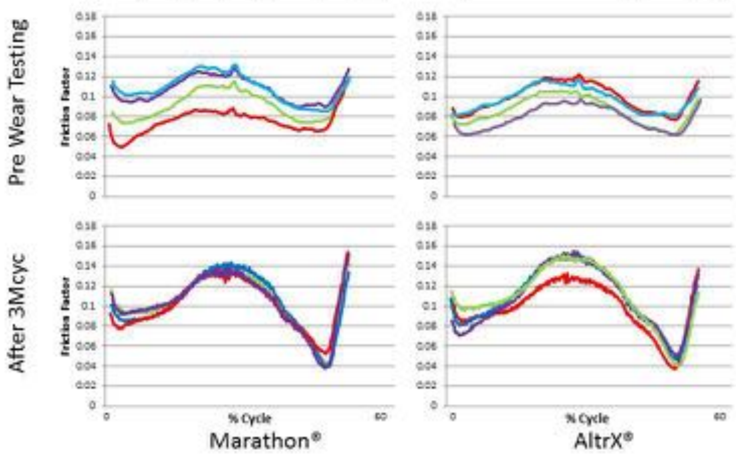

Figure 2

Table 1: Average wear, roughness and friction factors measured for all polyethylene test groups.

Group	Group ID	Wear Rate (mg/Mcyc) 0.5-3.0 million cycles	Pre Wear Testing (0Mcyc)		Post Wear Testing (3Mcyc)	
			Liner Roughness Ra (µm)	Friction Factor (± Std. Dev.)	Liner Roughness Ra (µm)	Friction Factor (± Std. Dev.)
A	Marathon®	10.3 ± 2.2	1.17	0.094 ± 0.015	0.09	0.103 ± 0.001
B	AltrX®	1.7 ± 0.2	1.25	0.095 ± 0.007	0.07	0.106 ± 0.006

Figure 3

First in Vitro Motion-Load-Motion Wear Test of Reverse Shoulder Replacements

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INTRODUCTION

Shoulder joint prostheses have become the most commonly replaced after knees and hips. Reverse shoulder arthroplasty (RSA) is a treatment option for patients with severe osteoarthritis, rotator cuff arthropathy or a massive rotator cuff tear with pseudoparalysis. Though successful, the long term survival of such implants are limited by wear of the materials in contact [1,2]. The aim of this study is to investigate RSA wear *in vitro* using a clinically relevant activity of daily living (ADL).

MATERIALS AND METHODS

Four new JRI Orthopaedics Reverse Shoulder 42 mm diameter VAIOS with Cobalt Chromium (CoCr) Glenoid Domes and ultra-high-molecular-weight-polyethylene (UHMWPE) Inverse Humeral Heads were tested. A five million cycles wear test was undertaken using the unique Newcastle Shoulder Wear Simulator with dilute bovine serum as a lubricant. “Mug to mouth” was performed as the ADL to the test prostheses in intervals of 100 cycles, following by 5 seconds of high load (450N) with no motion simulating an ADL such as “lifting an object”. This combined load cycle was then repeated. A fifth reverse shoulder prosthesis was subject to dynamic loading only in a control station. Wear was assessed gravimetrically and roughness (Sa) of the articulating surfaces was measured with a non-contacting profilometer.

RESULTS AND DISCUSSION

The mean wear rate and standard deviation of the UHMWPE components was 11.4±2.6 mm^3/million cycles, while the CoCr components showed minimal wear over the test duration 0.01± 0.02 mm^3/million cycles (Fig.1). Wear rates are comparable with Kohut et al [3] (14.0 mm^3/million cycles) and Smith et al [4] (14.3±1.6 mm^3/million cycles). The CoCr glenoid domes roughness was unchanged, from 32±3 nm Sa to 28±5 nm Sa over the 5 million cycles of the test ($p=0.017$), while the UHMWPE inverse humeral heads became smoother, from 692±19 nm Sa to 47±18 nm Sa (Fig.2), showing a significant change ($p<0.001$).

CONCLUSION

The present study is the first wear test of artificial shoulder joints using a Motion-Load-Motion configuration as a clinically relevant physiological pattern of motion and load. Results are comparable with the literature for in vitro testing of reverse shoulder replacements.

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Figures

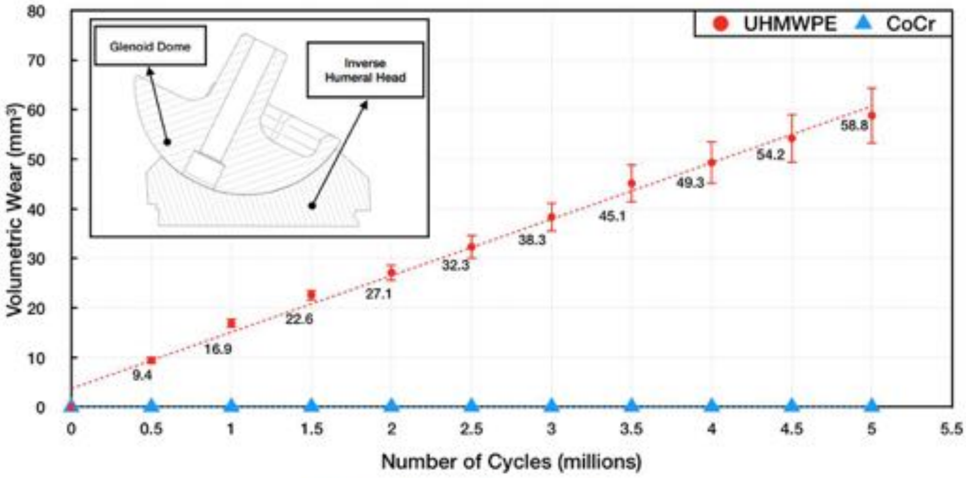

Figure1 Average Volumetric Wear

Figure 1

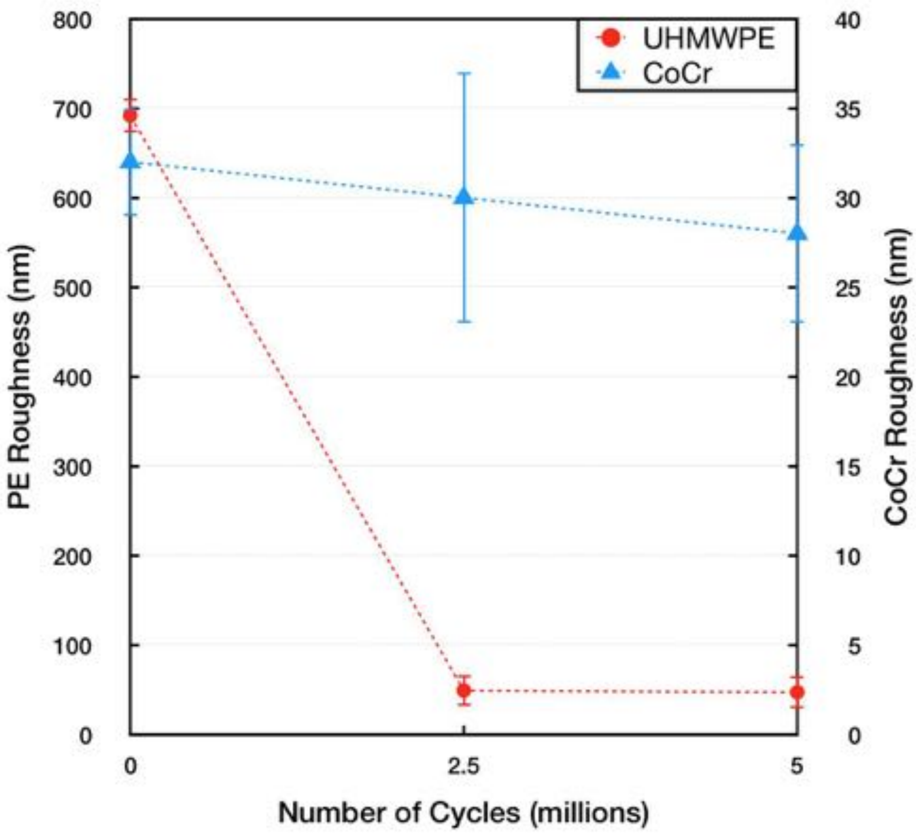

Figure2 Mean Articulating Surfaces Roughness

Figure 2

#5586

In Vitro Wear Testing of a New Prosthetic Shoulder System in Anatomic Configuration

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Background

The current use of a spherical prosthetic humeral head in total shoulder arthroplasty results in an imprecise restoration of the native geometry and improper placement of the center of rotation, maintained in a constant position, in comparison to the native head and regardless of glenoid component conformity.

A radially-mismatched spherical head to allow gleno-humeral translation is a trade-off that decreases the contact area on the glenoid component, which may cause glenoid component wear. This finding suggests that the use of a non-spherical head with a more conforming glenoid component may reduce the risk of glenoid component wear by allowing gleno-humeral translation while increasing the contact area.

A non-spherical prosthetic head more accurately replicates the head shape, rotational range of motion and gleno-humeral joint kinematics than a spherical prosthetic head, compared with the native humeral head. The combination of inversion of the bearing materials with the non-spherical configuration of the humeral head may thus decrease polyethylene wear.

Aim of the present study is to evaluate in vitro wear behaviour of an all-polyethylene elliptical humeral head component against a metallic glenoid component in an anatomic configuration.

Material and methods

The prosthetic components tested are from the Mira® Modular Shoulder System by Permedica S.p.A.. The prosthetic bearing components were tested in their anatomic configuration: the humeral head rubbing against the glenoid inlay, assembled over the glenoid base-plate.

The glenoid insert is made of Ti6Al4V alloy coated with TiNbN. The glenoid insert, as the glenoid base-plate have the same shape which reproduce the native shape of the glenoid. Moreover, the glenoid insert has a concave articular surface described by two different radii on orthogonal planes.

The vitamin E-blended UHMWPE humeral head is not spherical but elliptic-shaped with an articular surface described by two different profiles in sagittal and coronal plane.

The component sizes combination tested have the greatest radial mismatches allowed between humeral head and glenoid insert.

The test was performed up to 2.5 million of cycles applying a constant axial load of 756 N.

Results

After 2.500.000 cycles the mean mass loss from the humeral head was 0.68 mg. The mean wear rate of the humeral head was 0.28 mg/Mc (SD 0.45 mg/Mc). The surface of the humeral heads showed an elliptical worn area with matt and polished areas with scratching. The surface of the TiNbN-coated glenoid insert counterparts did not show wear signs.

Conclusion

The tested prosthetic humeral head has a non-spherical shape with an elliptical base and 2 different radii on sagittal and coronal plane. Also the tested glenoid insert has 2 different radii on sagittal and coronal planes. This components geometry leads to a radial mismatch between head and glenoid on sagittal and coronal planes.

A different kinematics, allowing gleno-humeral translation while increasing the contact area, radial mismatch in different planes and the inversion of bearing materials may have a role in reducing component wear and may explain the extremely low wear rate found in the present study.

#6128

Analysis of Malpositioning of Total Knee Implants Under Dynamic Activities Using Musculoskeletal Multibody Simulation

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Introduction

Total knee replacement (TKR) is an established and effective surgical procedure in case of advanced osteoarthritis. However, the rate of satisfied patients amounts only to about 75 %[1]. One common cause for unsatisfied patients is the anterior knee pain, which is partially caused by an increase in patellofemoral contact force and abnormal patella kinematics. Since the malpositioning of the tibial and the femoral component affects the interplay in the patellofemoral joint and therefore contributes to anterior knee pain, we conducted a computational study on a cruciate-retaining (CR) TKR and analysed the effect of isolated femoral and tibial component malalignments on patellofemoral dynamics during a squat motion.

Methods

To analyse different implant configurations, a musculoskeletal multibody model [Fig.1-A] was implemented in the software Simpack V9.7 (Simpack AG, Gilching, Germany) from the SimTK data set by Fregly et al. [2]. The musculoskeletal model comprised relevant ligaments with nonlinear force-strain relation according to Wismans [3] and Hill-type muscles spanning the lower extremity. The experimental data were obtained from one male subject, who received an instrumented CR TKR [2]. Muscle forces were calculated using a variant of the computed muscle control algorithm. To enable roll-glide kinematics, both tibio- and patellofemoral joint compartments were modelled with six degrees of freedom by implementing a polygon-contact-model representing the detailed implant surfaces. Tibiofemoral contact forces were predicted and validated using data from experimental squat trials [2]. The validated simulation model has been used as reference configuration corresponding to the optimal surgical technique [2]. In the following, implant configurations, i.e. numerous combinations of relative femoral and tibial component alignment were analysed: malposition of the femoral/tibial component in mediolateral (±3 mm) and anterior-posterior (±3 mm) direction [Fig.1-B,C].

Results

Mediolateral translation/malposition of the tibial component did not show high influence on the maximal patellofemoral contact force (reference: 2089 N; lateralisation: 2095 N;

medialisation: 2070 N). Regarding the mediolateral translation of the femoral component, similar tendencies were observed. However, lateralisation of the femoral component (3 mm) clearly increased the lateral patella shift [Fig. 2-A] and medialisation of the tibial component (3 mm) led to a slightly increased lateral patella shift [Fig. 2-B]. Our results are in accordance with experimental studies [4].

Compared to the reference model, pronounced posterior translation of the tibial and femoral component resulted in a lower patellofemoral contact force, further increasing with higher anterior translation of the components [Fig. 3-A,B]. The translation of the tibial component showed smaller influence on the patellofemoral contact force than the translation of the femoral component.

Discussion

In our present study, the mediolateral malposition of the femoral and tibial component showed no major impact on patellofemoral contact force and contribution to anterior knee pain in patients with CR TKR. However, the influence of implant component positioning in anterior-posterior direction on patellofemoral contact force is evident, especially for the femoral component. Our generated musculoskeletal model can contribute to computer-assisted preclinical testing of TKR and may support clinical decision-making in preoperative planning.

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Figures

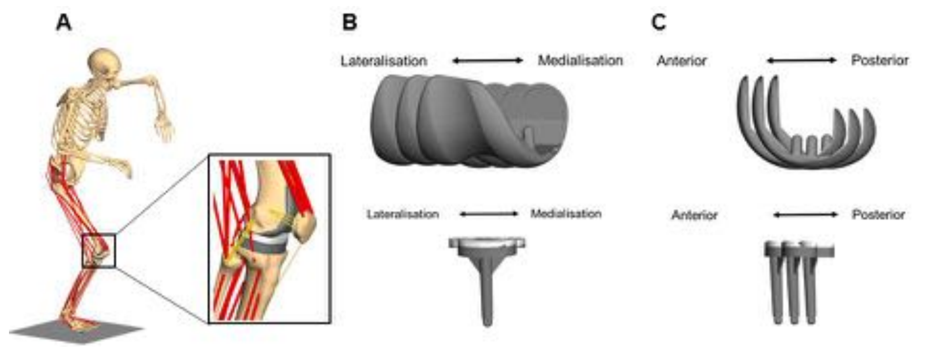

Figure 1

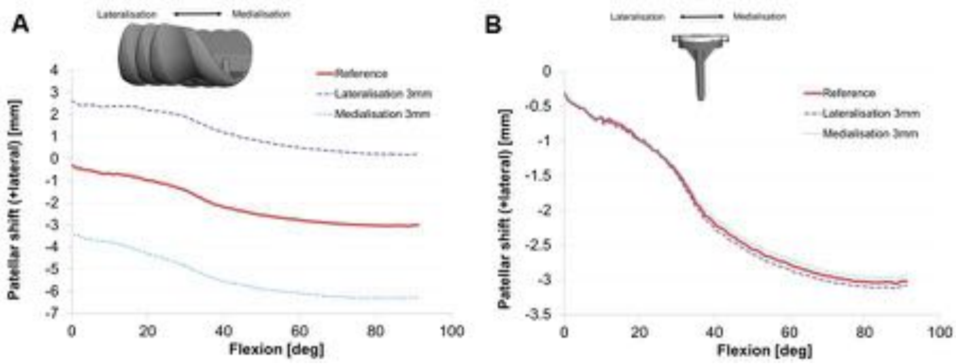

Figure 2

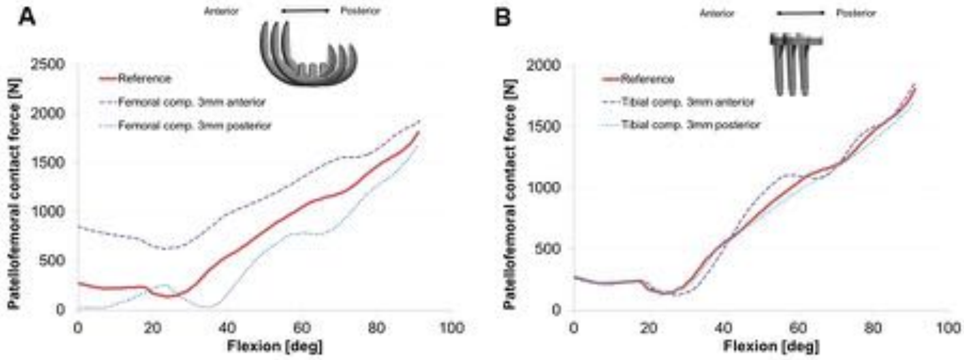

Figure 3

#5899

Influence of Posterior Tibial Slope on One-Year Postoperative Patient Satisfaction After Posterior-Stabilized Total Knee Arthroplasty

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Background

The posterior slope of the tibial component in total knee arthroplasty (TKA) has been reported to vary widely even with computer assisted surgery. In the present study, we analyzed the influence of posterior tibial slope on one-year postoperative clinical outcome after posterior-stabilized (PS) -TKA to find out the optimal posterior slope of tibial component.

Material and Method

Seventy-three patients with varus type osteoarthritic (OA) knees underwent PS-TKA (Persona PS^{R}) were involved in this study. The mean age was 76.6 years old and preoperative HKA angle was 14.3 degrees in varus. Tibial bone cut was performed using standard extra-medullary guide with 7 degrees of posterior slope.

The tibial slopes were radiographically measured by post-operative lateral radiograph with posterior inclination in plus value. The angle between the perpendicular line of the proximal fibular shaft axis and the line drawn along the superior margin of the proximal tibia represented the tibial slope angle (Fig. 1). We assessed one-year postoperative clinical outcomes including active range of motion (ROM), patient satisfaction and symptoms scores using 2011 Knee Society Score (2011 KSS).

The influences of posterior tibial slope on one-year postoperative parameters were analyzed using simple linear regression analysis ($p<0.05$).

Results

The average posterior tibial slope was 6.4 ± 2.0 °. The average active ROM were -2.4 ± 6.6 ° in extension and 113.5± 12.6 ° in flexion. The mean one-year postoperative patient satisfaction and symptom scores were 29.3 ± 6.4 and 19.6 ± 3.9 points respectively (Tab. 1). The active knee extension, satisfaction and symptom scores were significantly negatively correlated to the posterior tibial slope (r = -0.25, -0.31, -0.23). (Fig. 2).

Discussion

In the present study, we have found significant influence of the posterior tibial slope on the one-year postoperative clinical outcomes in PS-TKA. The higher posterior slope would induce flexion contracture and deteriorate patient satisfaction and symptom.

We had reported that the higher tibial posterior slope increased flexion gap and the component gap change during knee flexion in PS-TKA[1)]. Furthermore, another study reported that increase of the posterior tibia slope reduced the tension in the collateral ligaments and resulted in the knee laxity at flexion[2)]. The excessive posterior slope of tibial component would result in flexion instability, and adversely affected the clinical results including patient satisfaction and symptom.

Conclusion

In the PS-TKA for varus type OA knees, excessive tibial posterior slope was found to adversely affect one-year postoperative knee extension and clinical outcome including patient satisfaction and symptom. Surgeons should aware of the importance of tibial slope on one-year postoperative clinical results and pay more attentions to the posterior tibial slope angle not to be excessive.

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Figures

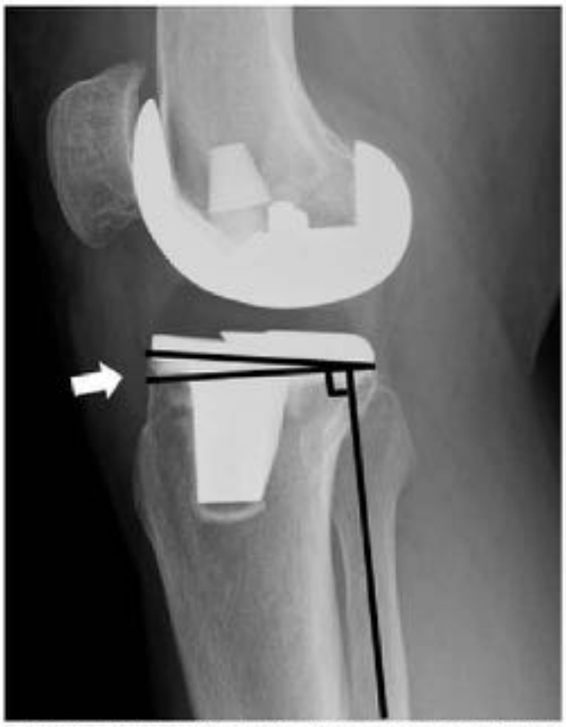

Figure 1: Postoperative lateral radiograph of the knee showing the method used to measure the tibial slope.

Figure 1

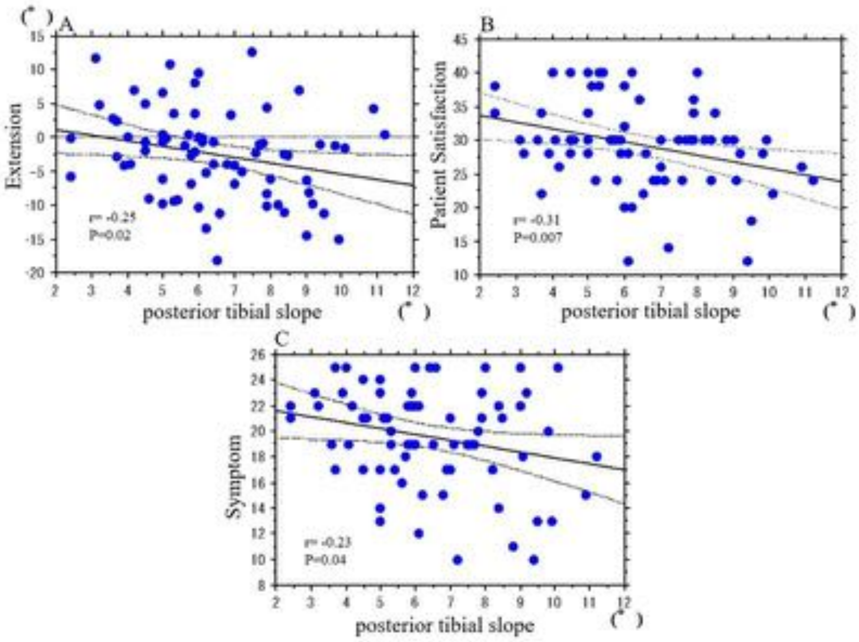

Figure 2: Influence of posterior tibial slope on one-year postoperative clinical outcome

A: active knee extension

B: patient satisfaction score

C: symptom score

Figure 2

Table 1: Means and r values (correlation coefficient) of each variable

Variables		**Mean (SD)**	**r value**	**p value**
ROM	Extension (°)	-2.4 (6.6)	-0.25	0.02
	Flexion (°)	113.5 (12.6)	0.02	0.87
2011 KSS	Patient satisfaction	29.3 (6.4)	-0.31	0.007
	Symptom	19.6 (3.9)	-0.23	0.04

Figure 3

#5843

Utility of the Skyline Radiograph in the Assessment of Malrotation in the Painful Total Knee Arthroplasty: a Radiographic Review

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Introduction: Malrotation of total knee arthroplasty (TKA) components has been proposed as a cause for pain, stiffness and patellar maltracking. Malrotation can be difficult to accurately assess on post-operative radiography, thus the gold standard imaging modality for diagnosis is two-dimensional computed tomography (CT) scan. Historically, a centered patellar position on skyline has been used by some to rule out malrotation as a cause of pain in TKA. This study aimed to test the validity of using a the skyline radiograph to rule out malrotation in the painful total knee as compared to the CT gold standard. The inter-observer reliability of measurements of rotation and patellar position between three observers was also assessed to measure the validity of the method.

Methods: We performed a retrospective radiographic review of patients who underwent CT scanning for a painful TKA. Patients with fracture or peri-prosthetic joint infection were excluded. Using an algorithm to search keywords on imaging requisitions and reports, all studies from January 2010 – December 2015 performed for malrotation or pain were examined and selected for analysis if the skyline radiographs were also available for review. Measurements of tibial, femoral and combined component rotation and a diagnosis of malrotation were made from CT scans. Measurements from skyline radiographs included patellar translation and tilt. Radiographic and CT measurements were performed separately by two arthroplasty fellowship trained surgeons and one fellowship trained musculoskeletal radiologist, blinded to each other's results, patients further imaging, and clinical findings. Intraclass correlation coefficients (ICC) between these readings were generated.

Results: Thirty-four patients had appropriate indications for scanning and complete imaging and were included into the study. Logistic regression showed no significant association between any of the radiographic measurements and a diagnosis of malrotation based on CT criteria ($P > 0.05$). The ICC measures (mean, 95% confidence interval) were very good for CT-based femoral 0.89 (0.81-0.94), tibial 0.75 (0.61-0.86), and combined 0.89 (0.81-0.94) rotation. Reliability was lower for radiographic measures of translation 0.62 (0.44-0.77) and tilt angle 0.66 (0.49-0.80).

Discussion and Conclusions: The position of the patella on skyline radiographs did not predict malrotation, and a normal skyline view did not rule out malposition in TKA. Despite metal hardware artifact, CT measurements for malrotation were highly reliable, while skyline radiographs led to less reliable measurements with poor correlation to CT measurements and are not should not be the sole investigation in the diagnosis of malrotation in TKA.

#6056

Accuracy of a Patient Specific Patella Guide, Relationships Between Patella Button Placement and Patient Reported Outcome

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Introduction & aims

Resurfacing of the patella is an important part of most TKA operations, usually using an onlay technique. One common practice is to medialise the patellar button and aim to recreate the patellar offset, but most systems do not well control alignment of the patella button. This study aimed to investigate for relationships between placement and outcomes and report on the accuracy of patella placement achieved with the aid of a patella Patient Specific Guide (PSG).

Method

A databse of TKR patients operated on by five surgeons from 1-Jan-2014 who had a pre-operative and post-operative CT scan and 6-month postoperative Knee Osteoarthritis and Outcome (KOOS) scores were assessed. Knees were excluded if the patella was unresurfaced or an inlay technique was used. All knee operations were performed with the Omni Apex implant range and used dome patella buttons. A sample of 40 TKRs had a patella PSG produced consisting of a replication of an inlay barrel shaped to fit flush to the patient’s patella bone.

The centre of the quadriceps tendon on the superior pole of the patella bone and the patella tendon on the inferior were landmarked. 3D implant and bone models from the preoperative CT scans were registered to the post-operative CT scan. The flat plane of the implanted patella button was determined and the position of the button relative to the tendon attachments calculated. Coverage of the bone by the button and patellar offset reconstruction were also calculated. The sample of 40 TKRs for whom a patella PSG was produced had their variation in placement assessed relative to the wider population sample. All surgeries were conducted with Omni Apex implants using a domed patella.

Results

A total of 322 patients were identified in the database, and 82 were subsequently excluded as inlay rather than onlay patella. 59% (142) were female and the average age was 68.9 years (+/- 7.2).

Coverage percentage of the cut patella surface by the button was 67% (± 7%), with 83% (200) knees having greater than 60%, and 40% (96) greater than 70%. Component position was on average centralised in terms of mediolateral position (0.09mm ± 1.93 lateral). When comparing the alignment of the patients whose knees used PSG guides with those who did not, it was found there was a statistically significant reduction in the variation that both external rotation error and flexional error had (p-values 0.048 and 0.022 respectively.)

Excess medialisation of the patella button was found to weakly correlate with reduced postoperative KOOS symptoms scores (coefficient=0.14, p-value = 0.035). When subdivided into patients who reported knee clicking sometimes or more often and those who did not, patients with highly medialised buttons had a 1.5x likelihood of reporting clicking of their knee joint (p-value = 0.036).

Conclusions

The patella-femoral joint remains a crucial component in the TKA knee, but the process of resurfacing the bone is not well controlled and can negatively influence patient outcomes. PSG's are one potential mechanism of controlling patella component alignment.

Figures

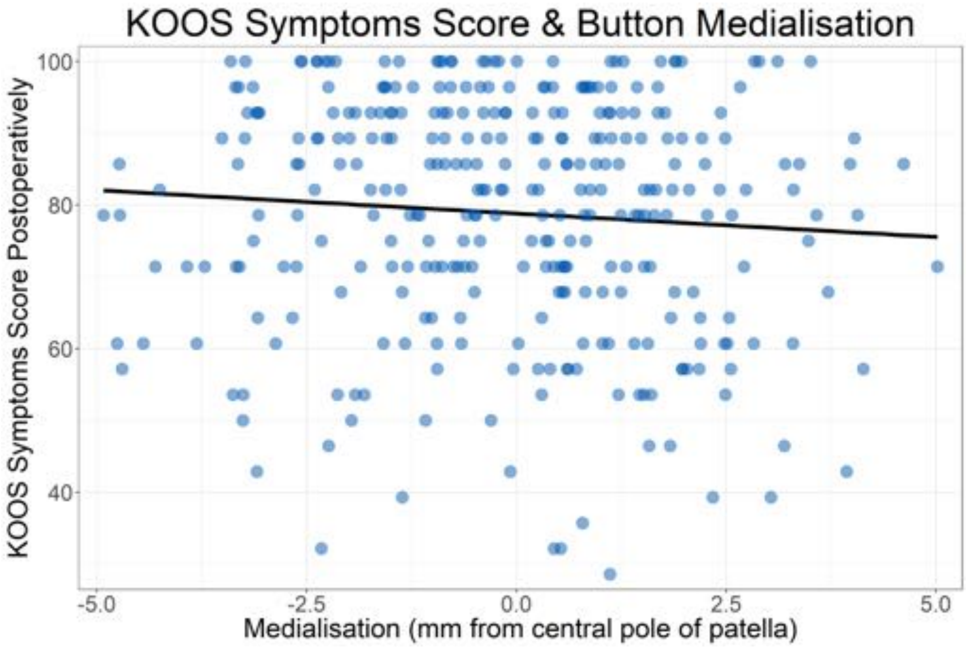

Figure 1

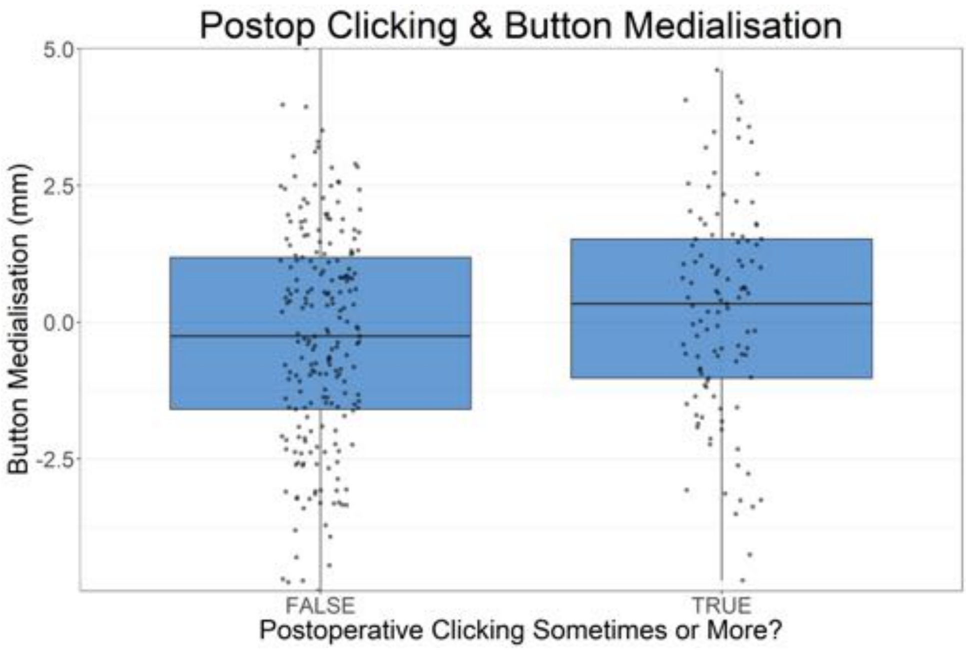

Figure 2

#6075

Mechanical Versus Kinematic Alignment in Total Knee Arthroplasty: Does the Bone Density Profile at the Implant-Tibia Interface Differ?

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Background:

Defining optimal coronal alignment in Total Knee Replacement (TKR) is a controversial and poorly understood subject. Tibial bone density may affect implant stability and functional outcomes following TKR. Our aim was to compare the bone density profile at the implant-tibia interface following TKR in mechanical versus kinematic alignment.

Methods:

Pre-operative CT scans for 10 patients undergoing medial unicompartmental knee arthroplasty were obtained. Using surgical planning software, tibial cuts were made for TKR with 7 degrees posterior slope and either neutral (mechanical) or 3 degrees varus (kinematic) alignment. Signal intensity, in Hounsfield Units (HU), was measured at 25,600 points throughout an axial slice at the implant-tibia interface and density profiles compared along defined radial axes from the centre of the tibia towards the cortices (Hotelling's t-squared and paired t-test).

Results:

From the tibial centre towards the lateral cortex, trabecular bone density for kinematic and mechanical TKR are similar in the inner 50% but differ significantly beyond this ($p= 0.012$). There were two distinct density peaks, with peak trabecular bone density being higher in kinematic TKR ($p<0.001$) and peak cortical bone density being higher in mechanical TKR ($p<0.01$). The difference in peak cortical to peak trabecular signal was 43 HU and 185 HU respectively ($p<0.001$). On the medial side there was no significant difference in density profile and a linear increase from centre to cortex.

Conclusions:

In the lateral proximal tibia, there is significantly less difference between peak cortical and peak trabecular bone densities in kinematic TKR compared to mechanical TKR. Laterally, mechanical TKR may be more dependent upon cortical bone for support compared to kinematic TKR, where trabecular bone density is higher. This may have implications for surgical planning and implant design.

#6040

Conservative Approaches to Kinematic Alignment and Their Impact on Patient Reported Outcomes

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Introduction & aims

Kinematic alignment has emerged as an alignment philosophy to challenge mechanical alignment, with a focus on restoring native anatomy. Conservative kinematic alignment approaches are emerging as a means of finding a compromise between these techniques(1).This study sought to investigate retrospectively if achieved TKA alignment technique correlated with short term patient outcomes.

Method

A database of TKR patients operated on by six surgeons from 1-Jan-2014 was accessed. All patients had a pre-operative CT scan segmented as part of routine surgical planning and a post-operative CT scan attained. Each patient had a mechanical and a kinematic surgical plan generated from the preoperative CT scan. A conservative kinematic alignment plan was also generated according to the technique described by Almaawi et al.(1), restricitng coronal component alignments to within 5° and combined coronal alignment to within 3° of neutral.

The achieved alignment was categorised as one of these three approaches from the post-operative CT scan and the relationship between these groupings and a 12-month postoperative Knee Osteoarthritis & Outcome Score (KOOS) was determined. All TKR's used Omni Apex implants.

Results

A total of 369 TKR knees were identified in the database. 60% (221) were female and the average age was 70.1 years (+/- 8.2). 21% (76) of the knees were classified as kinematically aligned, with 10% of the total (37) being conservative rather than fully kinematically aligned.

When binarising patients into those with a KOOS Pain score less than or greater than 70, a trend was found, with 76% (28/37) of the conservative kinematic alignment group, 88% (257/293) of the mechanically aligned group and 95% (37/39) of the full kinematically aligned group reaching the threshold low pain. When grouping the mechanically aligned group with the fully kinematically aligned group, this difference was statistically significant ($p = 0.0258$), with the conservatively kinematically aligned group having a 2.1x greater risk of failing to reach the 70-point threshold. This relationship remained significant when considering only patients whose anatomy was extreme enough to be modified by conservative kinematic alignment rules.

Conclusions

This study showed an increase in pain when the achieved alignment formed a compromise between a restorative and a reconstructive approach. This suggests that conservative approaches to kinematic alignment that maximise patient outcome may require selective application of kinematic alignment rather than blanket application of modified anatomical rules.

Figures

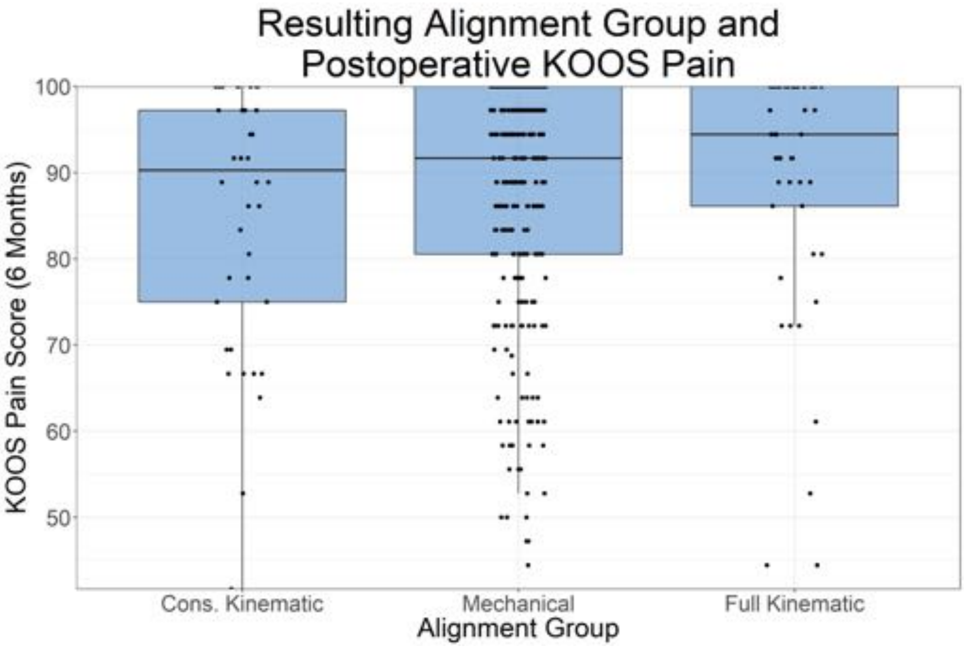

Figure 1

Clinical Outcome of Medial Pivot Compared With Posterior Stabilized Total Knee Arthroplasty in the Same Patients.

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Background

We use various implants of total knee arthroplasty in clinical practice and each presents specific design characteristics. We have hypothesized Medial pivot type(MP) total knee arthroplasty(TKA) implants to better replicate the natural kinematic of the knee.Our purposes were to compare clinical outcomes between MP TKA and posterior-stabilized(PS) TKA designs in the same patients.

Methods

We retrospectively compared the results of 10 patients (20 TKAs) with osteoarthritis and collected clinical outcomes on them with two different TKA implant designs on each knee. In both types, we used computer navigation and patient-specific cutting blocks manufactured using individual preoperative CT data. We assessed Knee injury and Osteoarthritis Outcome Score(KOOS) and range of motion preoperatively and at 1 year postoperatively.

Results

KOOS was not significantly different between the MP and PS types. However, there was a tendency that MP TKA had better Sport/Rec scores of KOOS than PS TKA at 1 year postoperatively (MP=50.0, PS=37.7, p=.28).There was no significant difference between the two designs with regards to range of motion. However, there was a tendency that PS TKA had more flexion than MP TKA at 1 year postoperatively(MP=123.2°, PS=130.5°, p=.17). There was no statistically significant difference in HKA preoperatively(MP=170.55°, PS=167.05°, p=.089). See figure 1.

Conclusions

We found that KOOS and range of knee motion were not significantly different between the MP and PS types at 1 year follow-up. However, the patients who underwent the MP-TKA scored better on Sport of KOOS and had less range of motion than those who underwent the PS-TKA. Future studies will involve larger cohorts and a randomized, controlled design.

Figures

Summary of Results of the Range of Motion, KOOS and HKA Between the MP and the PS Groups.

Measure Outcome	Preoperative			1y		
	MP Group	PS Group	P Value	MP Group	PS Group	P Value
Range of motion,°	117.27	114.09	.628	123.18	130.45	.188
Δ Range in motion,° (from preoperative)	n/a			5.91	16.36	
KOOS						
Pain	42.93	29.80	.127	83.59	81.57	.806
Symptom	51.30	32.79	.107	82.79	83.44	.909
ADL	59.36	49.06	.211	85.48	83.56	.719
Sport/Rec	15.91	10.91	.452	50.00	37.73	.276
QOL	26.14	19.89	.328	58.52	59.09	.950
HKA,°	170.55	167.05	.089			

MP medial pivot; PS posterior-stabilized

P<.05 was statistically significant.

Figure 1

#6175

Anterior Versus Posterior Approach Total Hip Arthroplasty: Patient Reported and Functional Outcomes in the Early Post-Operative Period

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Introduction

Direct anterior approach (DAA) total hip arthroplasty (THA) has been reported to improve early outcomes as compared to posterior approach THA up to 6 weeks post-operatively. However, very few detailed results have been reported within the first 6 weeks. In this study we investigate the effect of surgical approach on THA outcome via weekly assessment.

Methods

Patients undergoing THA for primary osteoarthritis were prospectively enrolled. Data was collected pre-operatively and post-operatively at weekly intervals for 6 weeks. Outcome scores and additional functional measures were compared using unpaired t-test, effect size, and Pearson correlation coefficients.

Results

111 patients (55 DAA and 56 posterior approach) were enrolled. There was no significant difference ($p>0.05$) in pre-surgical Patient Reported Outcome Measurement Information System (PROMIS) Pain interference and Physical Function scores, VAS Pain, and Modified Harris Hip Scores (mHHS).

Post-operatively, the DAA group had decreased length of stay [1.4 vs 2.2 days, $p=0.0002$] and increased distance walked on postoperative day 1 and 2 [95 vs 52 ft, $p=0.011$ and 251 vs. 163 ft, $p=0.0004$, respectively]. The DAA group had lower VAS pain scores [$p<0.05$] and required less day 1 and total narcotics [59 vs 80 morphine equivalents, $p=0.029$ and 138 vs 190, $p=0.01$, respectively]. The DAA cohort had improved PROMIS Physical Function scores and mHHS up to 5 weeks post-operatively. Anterior approach patients discontinued their assistive device 8 days earlier [$p=0.01$], left home 3 days earlier [$p=0.001$], and drove a car 5 days earlier [$p=0.016$] compared to posterior patients.

Conclusion

Patients undergoing DAA THA had significantly shorter length of stay, improved mobilization, decreased narcotic requirements and improved inpatient VAS pain scores compared to mini-posterior THA. Furthermore, DAA patients discontinued their assistive device, left their home, and drove a car sooner than posterior approach patients. The significant improvement in physical function seen with DAA THA persisted up to 5 weeks post-operatively.

Figures

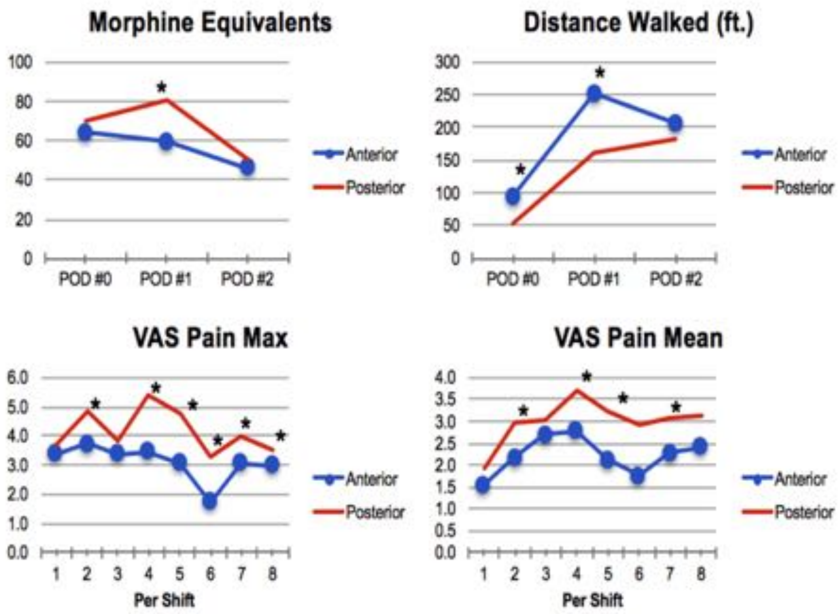

Figure 1

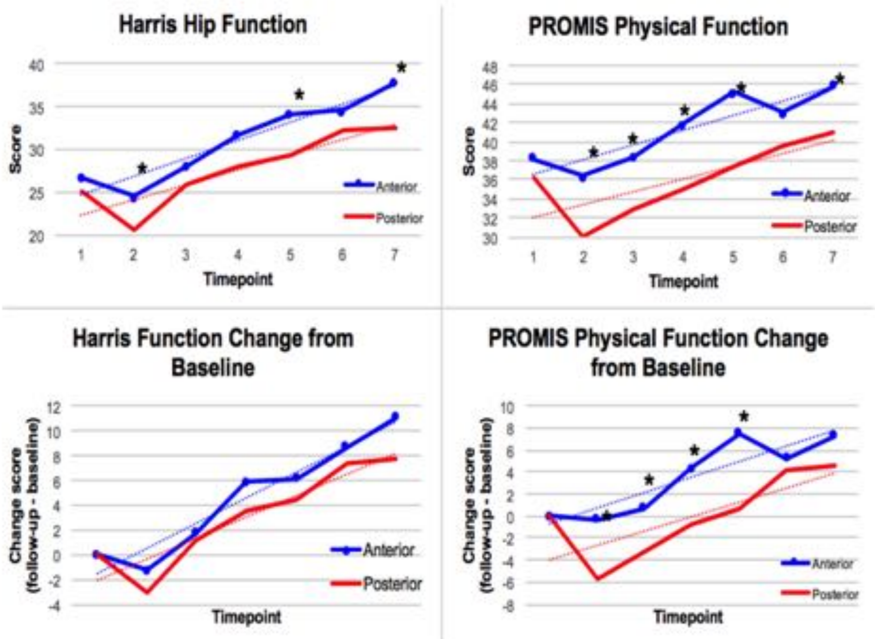

Figure 2

#5960

Effect of Smoking Status on Pain Intensity and Opioid Consumption in Total Hip Arthroplasty Patients

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Introduction: With increasing legislative pressures to optimize patient satisfaction and value of care, arthroplasty surgeons are tasked with improving recovery after total hip arthroplasty (THA). Previous studies have demonstrated some association between smoking and opioid use; however, no study evaluated association between smoking status and opioid consumption in THA patients. Therefore, we assessed 1) post-operative pain intensity; 2) lengths of stay; 3) patient perception of pain management; 4) immediate post-operative opioid consumption and 5) 90-day post-operative opioid consumption in smokers versus non-smokers.

Methods: Patients who underwent THA from 2010 to 2016 were propensity score matched 1:1 based on race, BMI, age, and sex. This yielded 124 smokers and 124 non-smokers **(Table 1)**. Pain intensity was quantified using Area under the Curve for Visual Analog Scale (VAS) pain scores. Opioid consumption was determined using a morphine milliequivalent conversion algorithm. An independent samples t-test and chi-square analysis was conducted to assess continuous and categorical variables respectively.

Results: Smokers experienced increased pain intensity (198.1 vs. 185.7)**(Table 2)** compared to non-smokers; although not statistically different (p=0.063). Smokers demonstrated higher opioid consumption in both immediate post-operative (65.9 vs. 59.3 mEq; p=0.045) **(Table3)** and 90 days post-operative periods (619.9 vs. 458.9 mEq; p=0.029).

Conclusion: Our study demonstrated increased pain intensity, and opioid consumption in both the immediate and 90-day post-operative periods following THA in patients who smoke cigarettes. This provides further reason to encourage pre-operative smoking cessation and surgeons should be aware of the potentially higher opioid demand and counsel patients accordingly.

Figures

Table 1. Patient Demographics between groups

	Smokers	Nonsmokers	p-value
Sample size (N)	124	124	
Mean age (range)	63.2 (28 to 90)	65.3 (24 to 91)	0.106
Mean BMI (range). kg/m2	28.8 (19.4 to 48.2)	29.9 (16.9 to 63.1)	0.096
Pre-Op VAS Scores	3.2 (0 to 10)	3.3 (0 to 10)	0.969
Females (%)	76 (61.3%)	68 (54.80%)	0.367
Males (%)	48 (38.7%)	58 (45.2%)	
Charlson Score			
0	72 (58.1%)	63 (50.8%)	0.312
1	22 (17.7%)	28 (22.6%)	
2	20 (16.1%)	19 (15.3%)	
3 or greater	10 (8.1%)	14 (11.3%)	
ASA Score			
ASA I	4 (3.3%)	5 (4.0%)	0.241
ASA II	84 (70.0%)	75 (60.5%)	
ASA III	32 (26.7%)	43 (34.7%)	
ASA IV	0 (0.0%)	1 (0.8%)	
Anesthesia Type			
Spinal	36 (29%)	45 (36.3%)	0.118
General	88 (71.0%)	79 (63.7%)	

Figure 1

Table 2. Comparison of Length of Stay and Pain Perception between Smokers and Nonsmokers

	Smokers	Nonsmokers	P Value
Median Length of Stay in Days	2.0 (0.0 to 10.0)	2.0 (1.0 to 7.0)	0.467
Pain Intensity (AUC)	198.1 (0.0 to 400.0)	185.7 (16.0 to 352.0)	0.063
Need Medicine for Pain			
Yes	112 (90.3%)	114 (91.9%)	0.563
No	12 (9.7%)	10 (8.6%)	
Pain Well Controlled			
Never	0 (0.0%)	2 (1.6%)	0.214
Sometimes	6 (5.3%)	2 (1.6%)	
Usually	39 (31.6%)	36 (29.0%)	
Always	78 (62.9%)	84 (67.7%)	
Mean Pain Rating	3.7 (2.0 to 4.0)	3.7 (1.0 to 4.0)	0.889

Figure 2

Table 3. Opioid Consumption between Smokers and Nonsmokers

	Smokers	Nonsmokers	p-value
Opioid Consumption, 48 hours	65.9 (0.0 to 337.7)	59.3 (0.0 to 327.0)	0.045
Opioid Consumption, 90 days	619.9 (0.0 to 5985.0)	458.9 (0.0 to 5340.0)	0.029

Figure 3

#5962

Relationship Between Muscle Strength and Functional Level in Patients With Revision Total Knee Arthroplasty

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Background: Revision total knee arthroplasties (rTKA) are performed with increasing frequency due to the increasing numbers of primary arthroplasties, but very little is known regarding the influence of muscle strength impairments on functional limitations in this population.

Objectives: The aim of this study was to assess relationship between muscle strength and functional level in patient with rTKA.

Design and Methods: Twenty-three patients (8 males, 15 females) were included in the study with mean age 68.4±10 years. Patients performed 3 performance tests (50-Step Walking Test, 10 Meter Walk Test, 30-Second Chair-Stand Test), and one self-report test (HSS) were preferred to assess patients. The maximum isometric muscle strength of quadriceps femoris and hamstring muscles of all the patients was measured using Hand-Held Dynamometer (HHD).

Results: While moderate-to-strong significant correlations was found between quadriceps femoris muscle strength and 30-Second Chair-Stand Test ($r=0.390$, $p=0.049$), 50-Step Walking Test ($r=-0.530$, $p=0.005$), 10 Meter Walk Test ($r=-0.587$, $p=0.002$), there were not significant correlation between HSS knee score and all performance-based tests ($p>0.05$). Also there were not significant correlation between hamstring muscle strength and all other measurement tests ($p>0.05$).

Conclusion: The moderate-to-strong statistical significant correlation between quadriceps femoris muscle strength and functional performance tests suggests that improved postoperative quadriceps strengthening could be important to enhance the potential benefits of rTKA.

Key Words: muscle strength, functional outcome, revision knee arthroplasty

#5967

The Effect of Pain and Kinesiophobia Level on Postoperative Functional Outcomes in Patients With Total Knee Arthroplasty

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Background: Kinesiophobia is simply defined as a fear of movement and physical activity. It can be seen in patients as a result of any injury, which results in pain or a fear of injury recurrence. It leads to decreased motion and disuse that may result in a chronic pain syndrome and decreased physical function. High levels of fear-avoidance have been found in subjects with total knee arthroplasty (TKA) and knee injuries, which predisposes them to the development of chronic pain conditions and seriously affect functional outcomes and their return to previous activity levels. However, the relationship between pain, kinesiophobia and performance-based outcomes in assessment of patients with TKA is unclear.

Purpose: The aim of our study was to investigate relationship between pain, kinesiophobia and performance-based tests in assessment of patients with TKA.

Methods: Twenty-eight patients (10 males, 18 females) were included in the study with mean age 63.6±9.8 years. Patients performed 2 performance tests (Timed "Up & Go" Test (TUG), 10 Meter Walk Test (10-MWT)) and one self-report measurement (TAMPA Scale) which measure the kinesiophobia were preferred to assess patients. Also the activity pain level was evaluated by The Numeric Pain Rating Scale (NPRS). Patients were evaluated preoperatively and at discharge.

Results: While there was a moderate significant correlation in preoperatively between activity NPRS and 10-MWT score ($r=0.432$, $p=0.022$), there was no correlation between activity NPRS and TUG ($p>0.05$). Also there were no correlations between TAMPA scale and 2 performance-based tests in preoperatively ($p>0.05$). There were high significant correlations between TAMPA scale and 2 performance-based tests (TUG, 10-MWT) in the evaluation of patients with TKA (respectively; $r=0.899$, $p<0.001$; $r=0.608$, $p=0.001$). However, there were no correlations between activity NPRS and 2 performance-based tests in postoperatively in patients with TKA.

Conclusion: While there were high significant correlations between TAMPA scale and 2 performance-based tests, there were no correlations between activity NPRS and 2 performance-based tests in postoperatively in patients with TKA. The functional level at early stage after TKA may be more related with the kinesiophobia level than the activity pain level. Given these results suggest that the rehabilitation after TKA focused on reducing kinesiophobia level could be important to enhance the potential benefits of the patients' functional outcomes at early stage after TKA.

Key words: Kinesiophobia, Pain Level, Functional Outcomes, Total Knee Arthroplasty.

#5516

: Post TKR Home Physiotherapy for a Period of 6 Weeks Reduces the Rate of Post TKR Manipulation Under Anesthesia (MUA) Rate

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OBJECTIVE: Post TKR manipulation under anesthesia is required when post operatively patients don't achieve desired range of motion. The rates quoted in various western literature ranges from 1 to 2 %. A knee is considered to be stiff when the patient fails to achieve 60 degrees of flexion. The objective of the study was to find out the differentiating factor responsible for low rate of MUA in Indian post TKR patients as compared to Anglo-Saxon population

MATERIAL & METHODS: We studied 100 consecutive patients operated from January 2016. The following parameters of these 100 patients were recorded.

1.Pre-op ROM

2.Age and Sex of the TKR patient

3.Duration of home physiotherapy

4.Post op ROM

All patients received post operative physiotherapy at home every day for first 2 weeks, 3 times week physiotherapy for next 2 weeks and then once a week for next two weeks

RESULTS: Of the 300 TKR patients 270 were females and 30 were males. The age range for male patients was 65 to 87 years with a mean of 73 years. The age range of female patients was 65 to 83 years with a mean of71 years. The mean range of motion achieved was 121 degrees. Only one of our patient required manipulation under anesthesia.(0.333%)

CONCLUSION: Our rate of MUA is totally different from that of reported from Western world. According to us home physiotherapy is the main differentiating factor responsible for this low rate. Hence we strongly advocate personalized home physiotherapy post TKR with constant feedback mechanism between the operating doctor and the treating physiotherapist.

#6199

Preparation of rGO/HA Composite Scaffold and Study on Osteogenesis Effect of It in Vitro and in Vivo

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Objective: Preparation of reduced graphene oxide-hydroxyapatite composite scaffolds (rGO/HA) was used to evaluate the biocompatibility in vitro and the effect on osteogenic differentiation of bone marrow mesenchymal stem cells (BMSCs). The ability of the composite scaffold to repair bone defects was thenverified in vivo.

Methods: 1. Synthesis and physicochemical characterization of rGO/HA composite scaffolds. 2. In vitro biosafety and osteogenic performance of rGO/HA composite scaffolds. 3. Repair of rat femoral segmental bone defects in vivo with rGO/HA composites.

Results and Conclusion The rGO/HA composites have good biosafety. The 0.3% rGO/HA composite exhibits the best biological activity in vitro. It can promote the adhesion and proliferation of mBMSCs, and differentiation into the osteogenic direction. The rGO/HA composite has good osseointegration and bone conduction capacity in vivo. It has a certain bone repair effect on the segmental bone defect. The rGO is a modified material with good application prospects in the field of bone tissue engineering bone repair. It is worth further research and development.

#5659

Fracture Toughness at the Interface Between Cortical Bone and Cancellous Bone

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Introduction

Bone fracture toughness is an important parameter in resistance of bone to monotonic and fatigue failure. Earlier studies on bone fracture toughness were focused on either cortical or cancellous bone, separately [1, 2]. Reported fracture toughness values indicated that cortical bone is tougher to break as compared to cancellous bone. In order to understand complete fracture of a whole bone, the interface between cortical and cancellous bone (named as corticellous bone) might play a crucial role and is interesting topic of research. The goal of this study was to identify fracture toughness in terms of J integral and fracture mechanism of the corticellous bone.

Material and Methods

Corticellous bone samples (single edge notch bend specimen or SENB) were prepared from bovine proximal femur according to ASTM E399-90 standard (Fig.1). For corticellous bone, samples were prepared in such way that approximately half of the sample width consist of cortical bone and another half is cancellous bone. Precaution was taken while giving notch and pre-crack to corticellous bone that pre-crack should not enter from cortical to cancellous portion. All specimens were tested using a universal testing machine (Tinius Olsen, ± 1 kN) under displacement rate of 100 µm/min until well beyond yield point. The fracture toughness parameter in terms of critical stress intensity (K_{IC}) was calculated according to ASTM E399-90 as given by,

$$K_{IC} = PS/BW^{1.5} * f(a/W) \quad \ldots \quad (1)$$

Where, P = applied load in kN, S = loading span in cm, B = specimen thickness in cm, W = specimen width in cm, a = total crack length, f(a/W) = geometric function. After the fracture test the J integral of each specimen was calculated using following equation. [ASTM E1820].

$$J_{total} = J_{el} + J_{pl} = K^2_{IC}/ E' + 2A_{pl}/Bb_0 \ldots (2)$$

Where, J_{el} is J integral of the elastic deformation, J_{pl} is J integral of the plastic deformation, $E'=E$ for plane stress condition and $E'= E/(1-\nu^2)$ for plane strain condition (E is elastic modulus; ν is Poisson's ratio), $b_o = W-a_o$, height of the un-cracked ligament, and A_{pl} is the area of the plastic deformation part in the load–displacement curve.

Result and Discussion

The fracture toughness in terms of critical stress intensity (K_{IC}) of corticellous bone was found to be 2.45 $MPa.m^{1/2}$. The plastic part of J integral, J_{pl} value of corticellous specimen was 9310 Jm^{-2}, and shown to be 27 times of the J_{el} value, 341 Jm^{-2}. Total J integral of corticellous bone was found to be 9651 Jm^{-2}. When crack travels through cortical portion and reaches at the interface, crack branching occurred and further it slows down (Fig.2). Indeed, more energy is required in plastic than elastic deformation.

Conclusion

J integral of corticellous bone is found to higher which is due to plastic deformation and crack branches at the interface between cortical and cancellous bone.

References

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[2] Cook RB, Zioupos P. The fracture toughness of cancellous bone. J biomech 2009; 42:2054-2060.

Figures

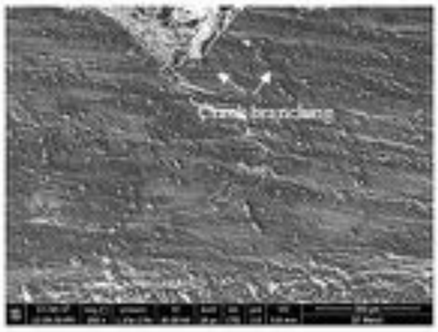

Figure 2. SEM image of crack profile of bovine corticellous bone: crack travels from the root of notch from cortical region, towards cancellous region, at the interface crack gets deflected and branching, slow down.

Figure 1

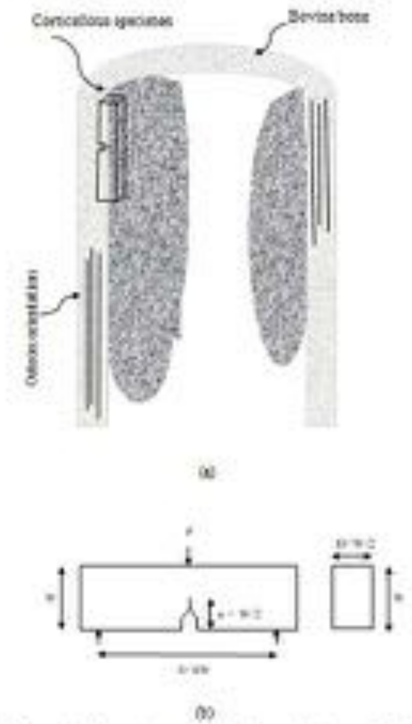

Figure 1. (a) Schematic representation of bovine bone showing corticellous specimen in transverse orientation. (b) Schematic representation of relation between specimen dimensions used for 3 point bending test.

Figure 2

Table 1. Bovine corticellous bone fracture properties. Two un-notched specimens were tested in each group to determine Young's modulus.

Properties	Corticellous bone (n = 10)
K_{IC} (MPa.m$^{1/2}$)	2.45 ± 0.3
E (GPa)	16.5 (16.3 and 16.7)
J_{el} (Jm^{-2})	341 ± 71
J_{pl} (Jm^{-2})	9310 ± 318
J_{total} (Jm^{-2})	9651 ± 320
K_{Jc} (MPa.m$^{1/2}$)	13.03 ± 0.5

Figure 3

#5578

The Effect of Material Heterogeneity, Element Type, and Down-Sampling on Trabecular Stiffness in Micro Finite Element Models

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INTRODUCTION: Trabecular bone transmits loads to the cortical shell and is therefore most active in bone remodeling. This remodeling alters trabecular material strength thereby changing the bending stiffness. Accounting for trabecular material heterogeneity has been shown to improve empirical-µFEM correlations by allowing for more realistic trabecular bending stiffness. In µFEMs to reduce computation time, region averaging is often used to scale image resolution. However, region averaging not only alters trabecular architecture, but inherently alters the CT-intensity of each trabeculae. The effect of CT-intensity variations on computationally derived apparent modulus (E_{app})in heterogenous µFEMs has not been discussed. The objectives of this study were to compare trabecular E_{app} among i) hexahedral and tetrahedral µFEMs, ii) µFEMs generated from 32 µm, 64 µm, and 64 µm down-sampled from 32 µm µ-CT scans, and iii) µFEMs with homogeneous and heterogeneous tissue moduli.

METHODS: Fourteen cadaveric scapulae (7 male; 7 female) were micro-CT scanned at two spatial resolutions (32 µm & 64 µm). Virtual bone cores were extracted from the glenoid vault, maintaining a 2:1 aspect ratio, to create µFEMs from the 32 µm, 64 µm, and down-sampled 64 µm scans. Custom code was used to generate µFEMs with 8-node hexahedral elements (HEX8), while maintaining the bone volume fraction (BV/TV) of each HEX8 32 µm model (BV/TV=0.24±0.10). Each virtual core was also generated as a 10-node tetrahedral (TET10) µFEM. All µFEMs were given either a homogeneous tissue modulus of 20 GPa, or a heterogeneous tissue modulus scaled by CT-intensity. All FEMs were constrained with identical boundary conditions and compressed to 0.5% apparent strain. The apparent modulus of each model was compared.

RESULTS: Comparing error in mean E_{app}, TET10 32 µm µFEMs with a homogeneous tissue modulus had an error of 7%, and a heterogeneous tissue modulus an error of 1% (Figure 1). Larger errors occurred for both down-sampled and scanned 64 µm µFEMs with both homogeneous and heterogeneous tissue moduli. The error in E_{app} as a function of trabecular thickness (Tb.Th*) was larger for µFEMs generated from 64 µm scans, than the down-sampled 64 µm µFEMs (Figure 2). The errors were lowest for Tb.Th* greater than 0.225 mm and for µFEMs generated with heterogeneous tissue moduli. The error in E_{app} as a function of volume fraction (BV/TV) was lowest above 0.225 for µFEMs with both homogeneous and heterogeneous tissue moduli and hexahedral and tetrahedral elements. Error was lower for the down-sampled 64 µm µFEMs versus scanned 64 µm µFEMs (Figure 3).

DISCUSSION: This study compared the E_{app} of linear isotropic µFEMs generated with hexahedral or tetrahedral elements from 32 µm, 64 µm, or down-sampled 64 µm µ-CT scans, with a homogeneous or heterogeneous tissue modulus. It was found that except at the highest spatial resolution, tetrahedral elements underestimate E_{app}. Down-sampling to half the original scan spatial resolution is not equivalent in E_{app} to FEMs generated from scans at that spatial resolution, and both models underestimate the E_{app} of the highest spatial resolution models. In general, accounting for trabecular material heterogeneity decreased errors in E_{app}.

Figures

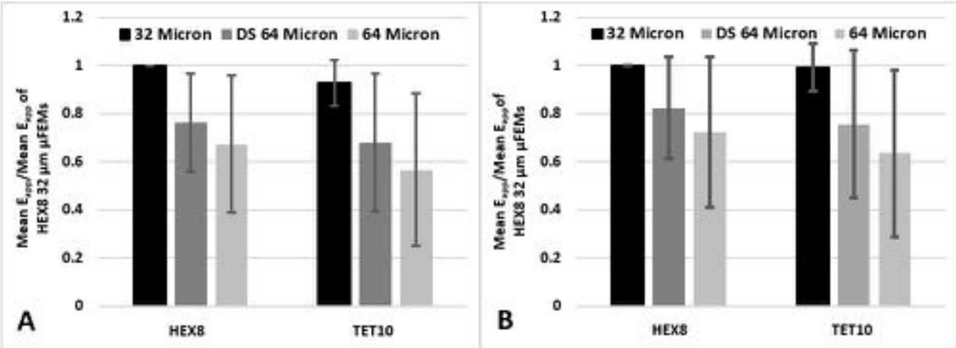

Figure 1: Mean error in apparent modulus (E_{app}) of µFEMs generated from 32 µm, 64 µm or down-sampled 64 µm micro-CT scans with hexahedral (HEX8) or tetrahedral (TET10) elements and a homogeneous **(A)** or heterogeneous **(B)** tissue modulus.

Figure 1

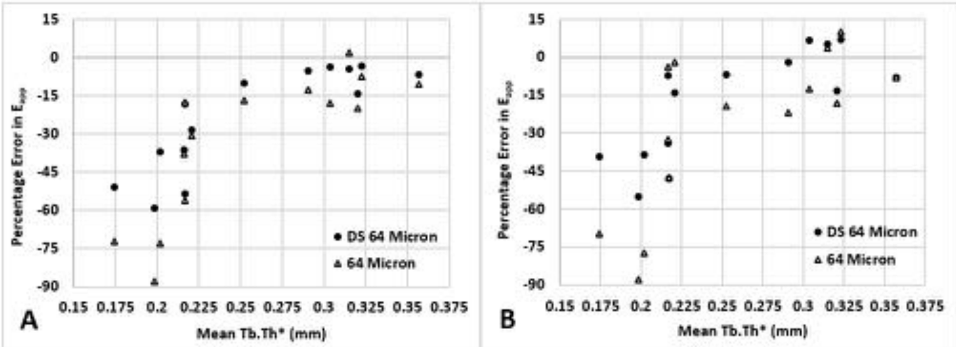

Figure 2: Percentage error in apparent modulus (E_{app}) of µFEMs generated from 64 µm or down-sampled 64 µm micro-CT scans with hexahedral elements and a homogeneous **(A)** or heterogeneous **(B)** tissue modulus, as a function of the 32 µm trabecular thickness (Tb.Th*).

Figure 2

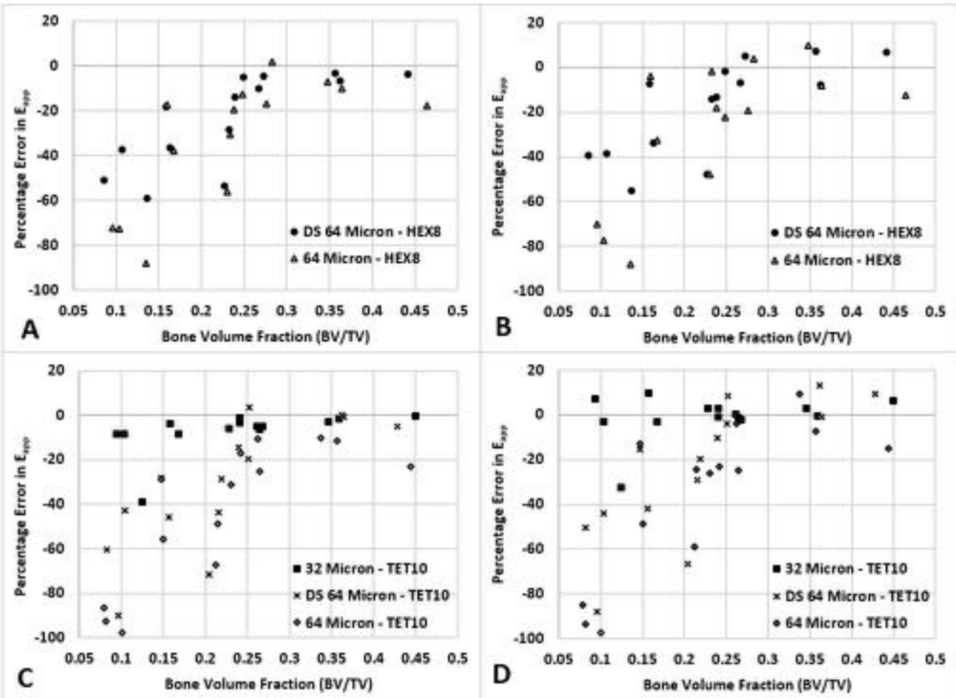

Figure 3: Percentage error in apparent modulus (E_{app}) of µFEMs generated from 32 µm, 64 µm or down-sampled 64 µm micro-CT scans with hexahedral elements and a homogeneous **(A)** or heterogeneous **(B)** tissue modulus, or tetrahedral elements and a homogeneous **(C)** or heterogeneous **(D)** tissue modulus.

Figure 3

#5645

Trabecular Titanium: Overview of the Biomedical Applications of an Advanced Cellular Solid Biomaterial.

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Introduction.

Trabecular Titanium is a biomaterial characterized by a regular three-dimensional hexagonal cell structure imitating trabecular bone morphology. Components are built via Electron Beam Melting technology in aone-step additive manufacturing process. This biomaterial combines the proven mechanical properties of Titanium with the elastic modulus provided by its cellular solid structure (Regis 2015 MRS Bulletin). Several in vitro studies reported promising outcomes on its osteoinductive and osteoconductive properties:Trabecular Titanium showed to significantly affect osteoblast attachment and proliferation while inhibiting osteoclastogenesis (Gastaldi 2010 J Biomed Mater Res A, Sollazzo 2011 ISRN Mater Sci); human adipose stem cells were able to adhere, proliferate and differentiate into an osteoblast-like phenotype in absence of osteogenic factors (Benazzo 2014 J Biomed Mater Res A). Furthermore, in vivo histological and histomorphometric analysis in a sheep model indicated that it provided bone in-growth in cancellous (+68%) and cortical bone (+87%) (Devine 2012 JBJS). A multicentre prospective study was performed to assess mid-term outcomes of acetabular cups in Trabecular Titanium after Total Hip Arthroplasty (THA).

Methods.

89 patients (91 hips) underwent primary cementless THA. There were 46 (52%) men and 43 (48%) women, with a median (IQR) age and BMI of 67 (57-70) years and 26 (24-29) kg/m2, respectively. Diagnosis was mostly primary osteoarthritis in 80 (88%) cases. Radiographic and clinical evaluations (Harris Hip Score [HHS], SF-36) were performed preoperatively and at 7 days, 3, 6, 12, 24 and 60 months. Bone Mineral Density (BMD) was determined by dual-emission X-ray absorptiometry (DEXA) according to DeLee &Charnley 3 Regions of Interest (ROI) postoperatively at the same time-points using as baseline the measureat 1 week. Statistical analysis was carried out using Wilcoxon test.

Results.

Median (IQR) HHS and SF-36 improved significantly from 48 (39-61) and 49 (37-62) preoperatively to 99 (96-100) and 76 (60-85) at 60 mo. ($p \leq 0.0001$). Radiographic analysis showed evident signs of bone remodelling and biological fixation, with presence of superolateral and inferomedial bone buttress, and radial trabeculae in ROI I/II. All cups resulted radiographically stable without any radiolucent lines. The macro-porous structure of this biomaterial generates a high coefficient of friction (Marin 2012 Hip Int), promoting a firm mechanical interlocking at the implant-bone interface which could be already observed in the operating room. BMD initially declined from baseline at 7 days to 6 months. Then, BMD slightly increased or stabilized in all ROIs up to 24 months, while showing evidence of partial decline over time with increasing patient' age at 60 months, although without any clinical significance in terms of patients health status or implant stability. Statistical significant correlations in terms of bone remodeling were observed between groups of patients on the basis of gender and age ($p \leq 0.05$). No revision or implant failure was reported.

Conclusions.

All patients reported significant improvements in quality of life, pain relief and functional recovery.Radiographic evaluation confirmed good implant stability at 60 months. These outcomes corroborate the evidence reported on these cups by orthopaedic registries and literature (Perticarini 2015 BMC Musculoskelet Disord; Bistolfi 2014 Min Ortop).

Ceramic on Ceramic Total Hip and Significant Trauma: What Risks?

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Introduction

Different publications about ceramic components in total hip arthroplasties, did insist on the risk of ceramic fracture after trauma. This is a major argument not to use this material. Many surgeon do advocate their patients not to perform heavy sports. In the current study we tried to address this question.

Material and Methods

Over à 40 years period we observed 14 fractures of a ceramic component. Only one could be attributed to a trauma. During the same period we looked at patients with a ceramic on ceramic implants who sustained heavy trauma and looked at the consequences on the ceramic.

Results

This study was conducted in two different institutions using the same ceramic on ceramic prosthesis manufactured by Ceraver* Company. We did record every consecutive patients that did sustain a significant trauma with consequences on their previously operated hip. Thirteen patient were found in our records. 10 males and 3 female aged 17 to 70 at time of index surgery. Type of accident were: four car accident, four motorcycle accident, five significant trauma after a fall, including one ski board trauma. These trauma occurred from 6 months to 15 years after index procedure. These trauma resumed in six fractures of the acetabulum with socket loosening in 4 that needed revision of the socket(figure 1), three femoral shaft fracture and revision of the stem as a consequence in two cases, three hip dislocations that were relocated, two of them needed further revision of the socket 4 and 10 years later, and one traumatic loosening of the socket that had to be exchanged. In one case associated to a fracture of the patella during a dashboard accident, a liner shipping was discovered during the revision. This is the only case of ceramic fracture. All other components remained intact; they were revised because of socket or stem loosening. One case of femoral fracture was only orifed(figure 2 and 3). This has to be compared with the 14 published cases of ceramic fracture. Only one was common, of the two series; 13 fractures were not related to significant trauma. Since this paper no fracture of ceramic head was observed; one liner fracture implanted in 2001 has to be exchanged.

Discussion and conclusion

This is a limited case study. But we can assume that Pure Alumina Ceramic materials are extremely resistant: reaching more than 100 KN for the femoral head. Only tangential impact on thin ceramic component could matter. Then we can conclude that in case of regular material well designed and manufactured, and also well implanted, the risk of fracture is not related to significant trauma and patients could be authorized to perform any heavy activities including sports. They can experience consequences of heavy trauma as everybody.

Figures

Figure 1

Figure 2

Figure 3

#5847

Chondrocytes on CH3â€“SAMs Form Cell Aggregation as on the Fibroin Substrate

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Introduction

In recent years, the new treatment method for osteochondral defects using “fibroin sponge covering” has been proposed. [1] Hirakata et al reported that osteochondral defects that were covered with the chondrocyte-seeded fibroin sponges showed hyaline cartilage-like repair. (Fig.1). They suggested that cell aggregates located near the fibroin sponge surface were delivered to the osteochondral defect to allow the early repair of large osteochondral defects.

It has been reported that chondrocytes cultured on fibroin substrates form cell aggregation after 12 to 24 hours after seeding, and the aggregation has been thought to have an important role to synthesize cartilage matrices without dedifferentiation. [2] In this study, morphological characteristics were compared between chondrocytes on fibroin substrates and chondrocytes on self-assembled monolayers (SAMs) of alkanethiols carrying different functional groups including methyl (CH_3), hydroxyl (OH), carboxylic acid (COOH), and amine (NH_2).

Material and methods

ã€€The cleaned glass plates were coated with a chromium underlayer of 1 nm and then a gold layer of 10 nm in thickness by a thermal evaporation apparatus (V–KS200, Osaka Vacuum Instruments, Osaka, Japan).The gold-coated plates were immersed in an ethanol solution of different alkanethiols at 1 mM for approximately 24 hours at room temperature to form the SAM.

Chondrocytes were isolated from the articular cartilages of 4-week-old Japanese white rabbits and seeded 1×10^5 cells onto fibroin coated plates and each SAMs coated plates. During a 24h culture period, time-lapse phase contrast images were captured every 10 minutes by a digital camera (DP70; Olympus, Japan). From the obtained image data cells were manually tracked and area, circularity, and aggregation rate of cells were acquired (Fig.2).

Results and Discussion

ã€€On CH_3– and OH–SAMs, the average area of cells was smaller than that on other SAMs, and the circularity of cells was higher than that on other SAMs. And there was no significant difference observed between CH_3– and OH–SAMs and fibroin substrate. In addition, the cell aggregation rate on CH3–SAMs was at the same level as that on fibroin substrate (Fig.3).

The results above suggest that chondrocytes on CH_3–SAMs form cell aggregation and may synthesize cartilage matrices without dedifferentiation, as on the fibroin substrate.

References

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[2] Otaka, A., Takahashi, K., Isshiki, K., Kambe, Y., Kojima, K., Tamada, Y., Tomita, N.,How do chondrocytes aggregate on fibroin substrate, 35th Annual International Conference of the IEEE EMBS, (2013).

Figures

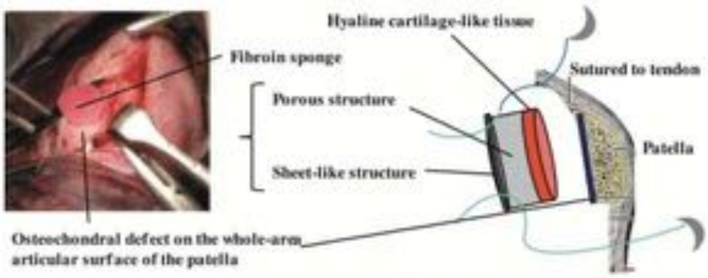

Fig.1. Cartilage repair using a fibroin sponge-based system was attempted for whole-area osteochondral defects of the rabbit patella.

Figure 1

Fig.2. Schematic viewing of experimental method.

Figure 2

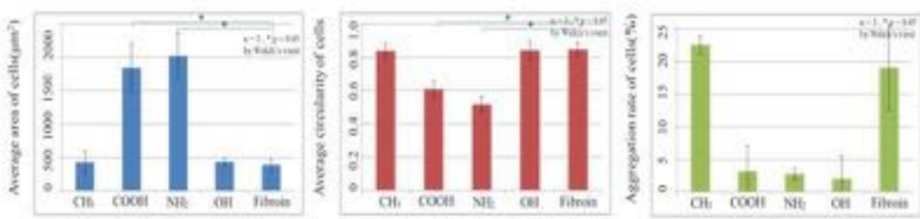

Fig.3. Average area, average circularity, and aggregation rate of cells on each substrate. (*:$p < 0.05$ by Welch's t-test)

Figure 3

#6198

Inhibition of Syndecan-4 Reduces Cartilage Degeneration in Murine Models of Osteoarthritis Through Downregulation HIF-2Î± via miR-96-5p

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The membranous receptor syndecan-4 (SDC-4) and the nuclear transcription factor hypoxia induced factors-2α (HIF-2α) play critical roles in the pathogenesis of Osteoarthritis (OA). However, little is known about the relationship among two factors and the mechanisms of osteoarthritis progression. miRNAs have recently emerged as key regulators of OA development and as mediators of the hypertrophic differentiation of chondrocytes and the cartilage degradation of OA cartilage.

We identified potential miRNAs related to OA development using miRNA microarray analysis, and found that miR-96-5p was up-regulated by SDC-4-specific antibodies in chondrocytes and cartilage tissue, and miR-96-5p can directly target the 3'-UTR of HIF-2α to inhibit the HIF-2α signaling in murine chondrocytes. Moreover, we demonstrate that, SDC-4-specific antibodies attenuated the IL-1β-induced chondrocyte hypertrophy and the cartilage degeneration by the inhibition of HIF-2α signaling via a miR-96-5p-dependent mechanism.

Our study revealed that the mechanisms and the relationship between SDC-4 and HIF-2α in the osteoarthritis progression and provides a potential therapeutic option for osteoarthritis.

#5590

Assesment of Micro Architexture of Bone and Biomechanical Properties of Proximal Femur for Hip Fractures Risk : A Pilot Study

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ASSESMENT OF MICRO ARCHITEXTURE OF BONE AND BIOMECHANICAL PROPERTIES OF PROXIMAL FEMUR FOR HIP FRACTURES RISK : A PILOT STUDY

DR RAJENDRA KUMAR KANOJIA

ABSTRACT:

BACKGROUND: Hip fractures are becoming more common now a days and showing increasing trend, particularly in asian population. Hip fractures are becoming a major source of mortality, morbidity and healthcare expenditure. Several researchers tried to predict hip fractures using DEXA scan and geometry. Recently, researchers also focussed on micro architecture of bone to in predicting hip fractures.

METHODS: It is a cohort study, where only patients with Unilateral Hip fracture were included, and the cause of fracture in every patient was trivial fall. We included 34 patients with Hip fracture, who underwent arthroplasty (hemi & total). We analysed clinical parameters , radiological parameters like DEXA and x rays, micro architecture and mechanical parameters. Clinical parameters included whether patient is diabetic, hypothyroid, hypovitaminosis D or any other abnormality. Radiological parameters includes, DEXA to know T scores and BMD levels. X ray parameters included proximal femur geometry from non fractured side like Hip axis length(HAL), Head trochantric length(HTL), Neck length(NL), Neck width(NW), Femur head diameter(FHD)& Neck length to Neck width ratio(NL:NW). Micro architecture parameters includes trabecular thickness, trabecular number, trabecular spacing and volume fraction. Mechanical parameters includes Modulus(Mpa), yield strength and ultimate strength using Finite elemental analysis. Modulus(Gpa) and hardness using nano indentation. We did linear regression method to know the correlation among these parameters.

RESULTS: We observed that as age increases Volume fraction decreases, trabecular number decreases, yield strength & ultimate strength decreased though not significant statistically. (IT group = 122.63, NOF group =125.06. we also observed that patients who suffered intertrochantric fracture had mean NSA of 122.63 & patients with Neck of femur had mean NSA of 125.06. We also found a positive correlation between BMD & volume fraction, yield strength & ultimate strength which were statistically significant($p < 0.05$). We also found statistically significant correlation($p<0.05$) between Neck length & Trabecular thickness, Head trochantric length & modulus(using nanoindentation).

CONCLUSION: In clinical scenario all surgeons see DEXA scan to categorize whether a patient is having weak bone or not. But from our study we observed that T-scores have no correlation to bone strength tested mechanically. Infact we found a significant correlation between geometrical parameters and biomechanical parameters Neck length & Trabecular thickness, Head trochantric length & modulus(using nanoindentation).

KEYWORDS: DEXA, Geometrical parameters, volume fraction, trabecular thickness, trabecular number, modulus, Finite elemental analysis & nano indentation.

Figures

Figure 1

Evaluation of the Implanted Position of microMAX Stem Using Pre-Operative Planning Software

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Introduction

Short-stem total hip arthroplasty (THA) makes minimally invasive approaches easier, preserves bone stock and reconstructs the physiological load transfer in the proximal femur. Good primary stability requires correct positioning of the stem in the femur. X-ray alone cannot adequately evaluate the stem position. We used THA pre-operative planning software for post-operative evaluation of the implanted stem position, with matching of the pre- and post-operative computed tomography (CT) femur data to create artifact-free data.

Subjects

This study was conducted on 10 hips from 7 patients who underwent THA using Revelation microMAX stem between March 2016 and October 2017 and who had pre- and post-operative CT available. The 7 patients consisted of 2 men and 5 women with a mean age of 61.7 years.

Methods

Pre- and post-operative CT images and femur data were matched automatically using the THA pre-operative planning software ZedHip (Lexi Co., Ltd., Tokyo). Computer-aided design (CAD) model data for the implants were superimposed onto the post-operative implant position data, and the CAD model data for the implants and pre-operative femur data were used for post-operative evaluation of the stem position. The femur-stem contact was measured using two methods. In one method, CT values of 600 and above were defined as the bone cortex, and the contact area with the stem was measured. In the other method, a space of 1.5 mm or less between the bone cortex and stem was used to indicate contact between the stem and bone cortex, and the contact area was measured.

Results

X-ray showed no sinking or migration of the stem in any cases. Three-dimensional measurements of the stem insertion angle showed a varus position of 2.58 2.57 and flexion of 3.18 1.23. Evaluation of the femur-stem contact based on CT values revealed that the stem tip and medial side were in contact with the femoral cortex in all cases, but the lateral side of the stem was in contact with the femoral cortex in only 1 of the 10 hips. When the contact was evaluated based on a space of 1.5 mm or less, the lateral flare of the stem was in contact with the femoral cortex in 9 of the 10 hips.

Discussion

X-ray cannot be adequately used to evaluate the position of the inserted stem. Our method allows evaluation based on the femur-stem contact on artifact-free CT images. As the proximal lateral femoral cortex is thin and produces low CT values, CT values alone are not sufficient for determining the femur-stem contact.

#5596

Effectiveness of CT-Based Navigation for Femoral Neck Cut in Total Hip Arthroplasty

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Background: Computed Tomography (CT) based navigation system is used to implant the prosthesis in appropriate alignment in total hip arthroplasty. However, little is known concerning the effectiveness for the stem implantation. The purpose of this study was to investigate the effects of CT-based navigation system for femoral neck cut on stem alignment and clinical outcome.

Methods: Sixty-five hips of 52 patients were included in this study. All surgeries were performed by two surgeons using an anatomical stem through posterolateral approach. Acetabular cup was implanted using navigation system. For femoral neck cut, 28 hips were operated using navigation system (navigation group), and 37 hips were operated without it in a conventional manner (non-navigation group). Using postoperative CT data, we measured stem alignment three-dimensionally (anteversion, sagittal tilt, and coronal angle) based on the retrocondylar plane, and evaluated the difference from preoperative planning. Furthermore, agreement of stem size between intraoperative decision and preoperative planning, stem subsidence, periprosthetic fracture, and dislocation were investigated. These results were compared statistically between two groups

Results: Postoperative anteversion change from preoperative planning was significant larger in navigation group than in non-navigation group (-6.2 ± 7.3°, -3.9 ± 3.3°, p = 0.01). There were no significant differences in the postoperative sagittal tilt and coronal angle (sagittal tilt; navigation group: -1.9 ± 2.2°, non-navigation group: -0.4 ± 2.5°, p = 0.05. coronal angle; navigation group: valgus 0.6 ± 1.6°, non-navigation group: valgus 0.3 ± 1.4°, p = 0.36). Intraoperative change of stem size from preoperative planning was occurred in 5 hips, and stem subsidence was occurred in 5 hips in non-navigation group, both of which were not seen in navigation group. There were significant differences in stem size change and stem subsidence (p = 0.02, p = 0.02). Periprosthetic fracture was occurred in 1 hip in non-navigation group, but there was no significant difference between two groups (p = 0.18). No dislocation was seen in all hips.

Conclusion: CT-based navigation system for femoral neck cut was effective in reducing stem subsidence. On the other hand, it was difficult to obtain the accuracy of stem anteversion with femoral neck cut navigation only.

#5716

The Need for Patient-Specific "Safe Zones" in Total Hip Arthroplasty

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Introduction: The purpose of this study was to compare pre-operative acetabular cup parameters using this novel dynamic imaging sequence to the Lewinnek safe zone

Methods: We retrospectively reviewed 350 consecutive primary THAs that underwent dynamic pre-operative acetabular cup planning utilizing a pre-operative CT scan to capture the individual's hip anatomy, followed by standing (posterior pelvic tilt), sitting (anterior pelvic tilt), and supine X-rays. Using these inputs, we modeled an optimal cup position for each patient. Radiographic parameters including inclination, anteversion, pelvic tilt, pelvic incidence, and lumbar flexion were analyzed.

Results: Mean age of patients was 63 years (range, 18 to 95). Mean supine pelvic tilt was 4.7o (range, -31o to 21o), standing pelvic tilt was -0.3o (range, -33o to 23o), and flex-seated pelvic tilt was -0.7o (range, -42o to 32o). Mean pelvic incidence was 54o (range, 24o to 88o) and mean lumbar flexion was 43o (range, 0o to 78o). Mean inclination was 40° (range, 34 to 49) and mean anteversion was 24° (range, 3.5 to 39). Only 56% of the dynamically planned cups were within the Lewinnek safe zone ($p<0.05$, Figure 1). Mean inclination and anteversion difference between dynamic and Lewinnek safe zone was 1.3o (range, 0o to 12o) and 8.9o (range, 0o to 25o), respectively.

Conclusion: Our study demonstrates that historical target parameters for cup inclination and anteversion significantly differ to target values obtained with the use of functional imaging. Understanding the individual spinopelvic motion for each patient allows for more accurate placement of the acetabular component, which may help to reduce the risk of dislocation, premature wear and squeaking of bearing surfaces, and improve functional outcomes.

The Patient Specific Template for Femoral Neck Cut and Adjustment of the Stem Alignment With the Modified Watson-Jones Anterolateral Approach

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Introduction

CT-based 3D-templating enable to make the preoperative planning more precisely than that based on plain radiography. However, even if the preoperative plan had been elaborated, it is unpredictably difficult to make implantation according to the plan. Patient specific template (PST) is one of resolutions for this problem. Recently, 3D-printer came to be enough cheap for private users. Using 3D-printer, we have made PSTs for femoral implantation with posterior approach (posterior PST), which precision and accuracy was comparable for CT-based navigation (37th SICOT). We have simultaneously developed PSTs for modified Watson-Jones anterolateral approach (anterior PST). However, it was difficult to set PST on the anterior surface of the femoral neck because of its smooth terrain, comparing the posterior surface of the femur with complex bony shape such as the fossa and ridge of the trochanter. We have made improvement in design to be anchored to the medial calcar to overcome this anatomical disadvantage, and anterior PSTs become to use with trust.

Objects

To validate the utility of the anterior PSTs designed to reproduce the preoperative planning on the femoral neck cut and stem alignment.

Methods

Twenty-five primary THAs (Optimys: 11, Kinectiv: 6, Microplasty: 3 and others: 5 hips) with anterior PSTs were included. Preoperative planning was made in all cases with 3D-templating software (ZedHip; LEXI, Tokyo). Two types of anterior PST were designed; one for the indication on the level and direction of the femoral neck cutting for stem valgus and flexion alignment, and the other for the stem anteversion (figure 1,2). They were made of polylactic acid with a fused deposition modeling 3D printer (Creator Pro, Apple Tree Co., LTD., Osaka). Stem anteversion, valgus and flexion angle, longitudinal position and leg length difference were measured by postoperative CT with the same software. Precision and accuracy of the implantation were respectively evaluated by mean absolute value (MAV) and standard deviation (SD).

Results

The average of MAV and SD were 5.4 and 4.1 degrees for anteversion, 1.3 and 1.2 degrees for valgus, 2.1 and 1.6 degrees for flexion, 2.2 and 1.3 mm for longitudinal position, and 2.2 and 1.5mm for leg length difference, respectively.

Discussion and Conclusion

Comparing valgus and flexion angle of the stem, the control of anteversion has to be improved, because we decide cup alignment according to so-called combined anteversion theory. Our anterior PSTs have as well precision and accuracy of the femoral implantation as our posterior PSTs. However, we have to make some improvement on anteversion control technology, unlike valgus and flexion angle.

Production of the broaching handle to firmly control the anteversion could be an answer. The development of the anteversion measuring device during broaching could also be a good method, because the marker of stem anteversion that was drawn on the neck cut section along PST was often disappeared by broaching.

Figures

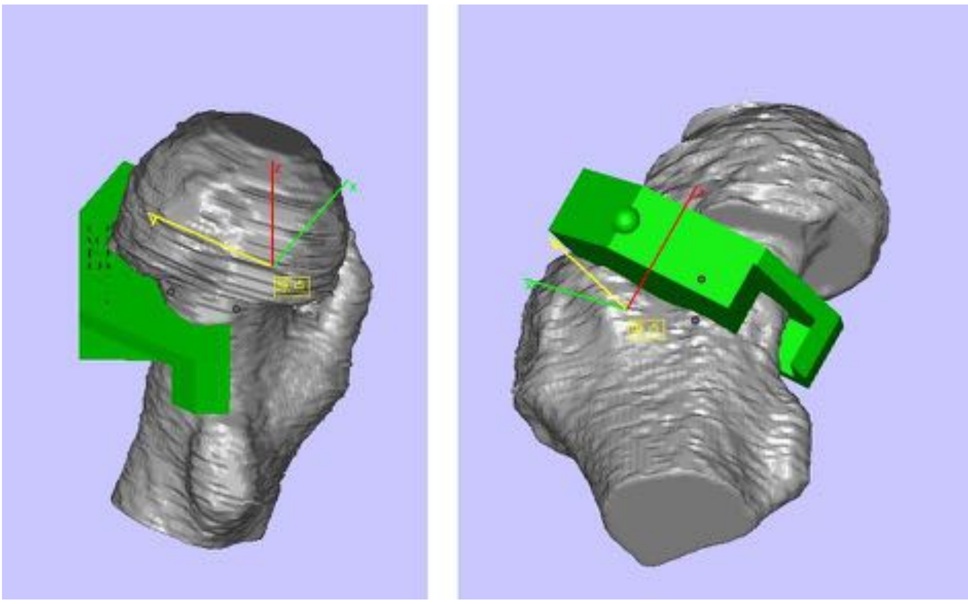

Figure 1

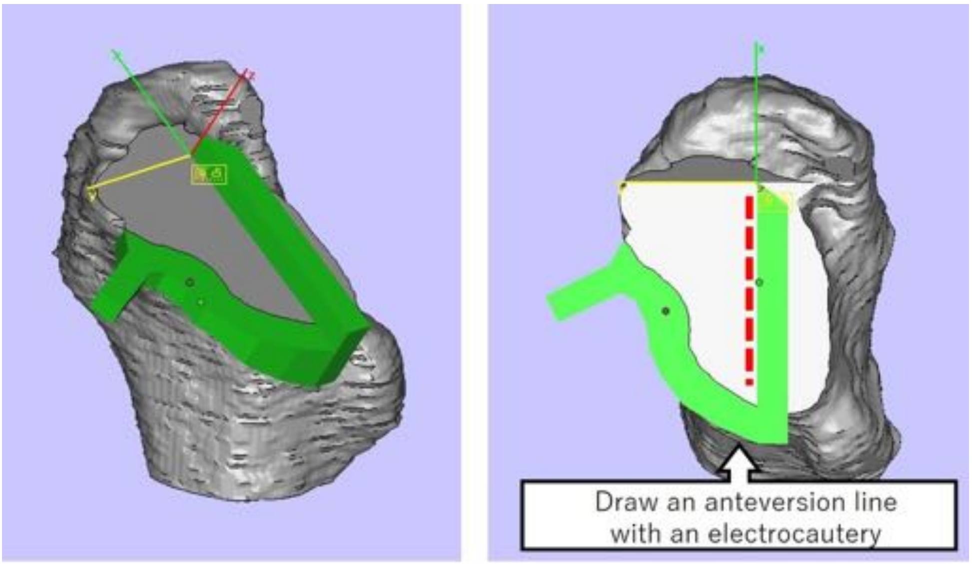

Figure 2

#6105

Clinical Accuracy of a Smart Mechanical Navigation System for Cup Alignment as Measured by Post-Operative CT

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Introduction: Studies repeatedly demonstrate that more than ½ of acetabular components placed during hip arthroplasty are significantly malpositioned[1] and that intraoperative radiographic assessment is unreliable. The current study uses postoperative CT to assess the accuracy of a smart mechanical navigation instrument system for cup alignment.

Patients and Methods: Fifty three hip replacements performed using a smart mechanical navigation device (the HipXpert System) had post-operative CT studies available for analysis. Thirty of these hips were in men, 23 in women. These post-operative CT studies were performed for pre-operative planning of the contralateral side, one to three years following the prior surgery. An application specific software module was developed to measure cup orientation using CT (HipXpert Research Application, Surgical Planning Associates Inc., Boston, Massachusetts). The method involves creation of a 3D surface model from the CT data and then determination of an Anterior Pelvic Plane coordinate system. A multiplaner image viewer module is then used to create an image through the CT dataset that is coincident with the opening plane of the acetabular component. Points in this plane are input and then the orientation of the cup is calculated relative to the AP Plane coordinate space according to Murray's definitions of operative anteversion and operative inclination. The actual cup orientation was then compared to the goal of cup orientation recorded when the surgery was performed using the system for acetabular component alignment.

Results: For the thirty seven hips replacements, mean operative anteversion error was 1.6 degrees (SD 3.7, range -5.5 to 8.7). Mean operative inclination error was -1.7 degrees (SD 3.1, range -8.0 to 5.6). There were no outliers in either anteversion or inclination.

Conclusion: The current study demonstrates that the mechanical navigation system produces accurate cup alignment results as measured by post-operative CT and confirms the prior accuracy study performed using 2D/3D matching. This improved accuracy compared to robotic systems[4] may be due to the wide-based nature of the docking mechanism and the elimination of the cumulative errors of registration and tracking inherent to more complex systems.

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#6117

Measuring Pelvic Tilt Using Inertial Measurement Units for Optimising Total Hip Arthroplasty

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Background: Over 10% of total hip arthroplasty (THA) surgeries performed in England and Wales are revision procedures[1]. Malorientation of the acetabular component in THA may contribute to premature failure. Yet with increasingly younger populations receiving THA surgery (through higher incidences of obesity) and longer life expectancy in general, the lifetime of an implant needs to increase to avoid a rapid increase in revision surgery in the future.

The Evaluation of X-ray, Acetabular Guides and Computerised Tomography in THA (EXACT) trial is assessing the pelvic tilt of a patient by capturing x-rays from the patient in sitting, standing and step-up positions. It uses this information, along with a CT scan image, to deliver a personalised dynamic simulation that outputs an optimised position for the hip replacement. A clinical trial is currently in place to investigate how the new procedure improves patient outcomes[2].

The requirement for multiple x-rays is a weakness of this approach: it is costly, exposes the patient to substantial radiation levels and still only provides a snap-shot of a limited set of movement positions. Our aim in this project was to assess whether accurate functional data could be obtained using inertial measurement units (IMUs) compared to X-rays.

Methods: Recruited patients were fitted with a bespoke device consisting of a 3D-printed clamp which housed the IMU and fitted around the sacrum area. A wide elastic belt was fitted around the patient's waist to keep the device in place. Pelvic tilt is measured in a standing, flexed seated and step-up position while undergoing X-rays with the IMU capturing the data in parallel. Patients further completed another five repetitions of the movements with the IMU but without the x-ray to test repeatability of the measurements. Statistical analysis included measures of correlation between the X-ray and IMU measurements.

Results: Data on 12 patients thus far indicates a moderate-strong correlation of R^2=0.92 (Figure 1) between IMU and radiological pelvic tilt measure of AP pelvic tilt.

Key message: A novel device has been developed that can suitably track pelvic movements to stratify patients into risk categories for post-operative dislocations.

References

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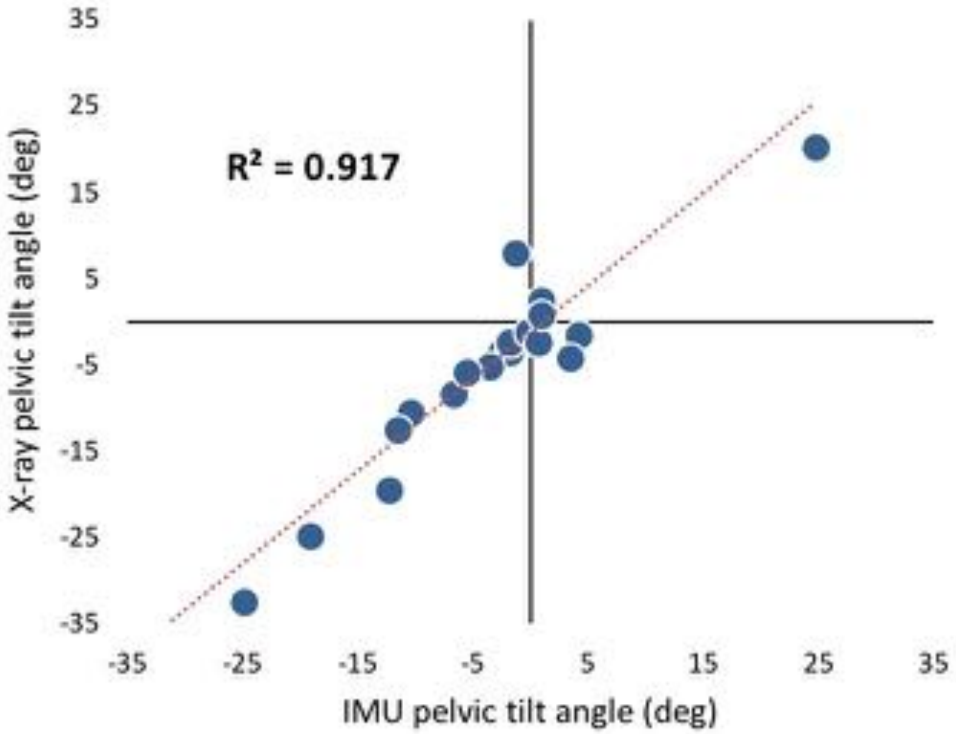
Figures



$R^2 = 0.917$
X-ray pelvic tilt angle (deg)
35
25
15
5
-5
-15
-25
-35
-35
-25
-15
-5
5
15
25
35
IMU pelvic tilt angle (deg)

Figure 1

#6045

Does an Intraoperative Measurement of Acetabular Cup Orientation Predict the Postoperative Acetabular Cup Orientation?

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Purpose: Acetabular component orientation in total hip arthroplasty is a major determinant of a successful long-term outcome. Instability is one of the most common complications following THA, and while the etiology can be multifactorial, malposition of cup is considered as the single most important variable. Intraoperative radiographic assessment is commonly used to assess and modify cup orientation. We aimed to determine if an intraoperative method of cup orientation measurement predicts the postoperative cup orientation. â€¨

Methods: A total of 54 patients 57 hips were included in this study. All patients had a preoperative pelvis CT, preoperative anteroposterior (AP) pelvis radiograph in the standing position, intraoperative AP pelvis radiograph in the lateral decubitus position, and 3 months postoperative AP pelvis radiograph in the standing position. An intraoperative radiographic measurement system was used to measure cup orientation on radiographs taken in the lateral decubitus position (Figure 1). Cup anteversion was calculated by drawing the ellipse of the acetabular cup's opening rim followed by determination of the short and long axes with the use of the Martell's method. All measurements were carried out by two independent observers, both orthopedic surgeons and both trained in the use of the system. Interobserver reliability was assessed by comparing the results of the two observers, who were blinded to each other's results. In order to check intraobserver reliability, each observer measured all hips two times with a one-month interval between measurements and without comparison to the previous measurements. Two-dimensional (2D)/three-dimensional (3D) matching software program was used for measurement of postoperative cup orientation, and pelvic tilt and rotation in the standing position (Figure 2). â€¨

Results: Intraoperative measurements compared to postoperative measurements of cup position were not significantly different for inclination p = .22), whereas the measurement of anteversion was significantly different between the two measurements (p = .03). 35% of inclination measurements were more than 5 degrees different, and 8% of measurements were more than 10 degrees different. For anteversion, 63% of measurements were more than 5 degrees different, and 23% were more than 10 degrees different. Pelvic tilt correlated with the differences in cup orientation between before and after 2D/3D matching. When all 57 hips were separated into right and left side, pelvic rotation directly correlated with the pelvic tilt-adjusted difference in anteversion between before and after 2D/3D matching of the left side (r2 = .85), but inversely correlated with that of the right side (r2 = .81). â€¨

Conclusion: An intraoperative measurement of cup anteversion in the lateral decubitus position does not predict the postoperative cup anteversion in the standing position. Variations of pelvic tilt and pelvic rotation by position (supine, lateral decubidus, standing) may significantly affect acetabular component measurements of inclination and anteversion, and may partly explain the variation seen in cup orientations in different positions. â€¨

#5618

Comparison of Synovial Fluid and Serum Procalcitonin for Diagnosis of Periprosthetic Joint Infection: A Prospective Cohort Study in 32 Patients

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Background

Periprosthetic joint infection (PJI) remains challenging as a “gold standard” for diagnosis has not yet been established. The aim of this study was to evaluate the accuracy of synovial fluid procalcitonin (SF-PCT) and serum procalcitonin as diagnostic biomarker for PJI and compared their accuracy with standard methods.

Materials and Methods

A single-centered prospective cohort study was conducted between 2015-2017 in 32 patients with painful hip or knee arthroplasty underwent revision surgery. Relevant clinical and laboratory data were collected. PJI was diagnosed based on the 2013 international consensus criteria. Preoperative blood sample and intraoperatively acquired joint fluid were taken for PCT measurement with a standard assay. Diagnostic accuracy was analyzed by the receiver-operating characteristic (ROC) curve and the area under the curve (AUC).

Results

Twenty patients (62.5%) were classified as PJI, and 12 of them (37.5%) were classified as aseptic loosening group. The median age was 68 years (range 38-87 years). The median values of SF-PCT and serum PCT in PJI group were both significant higher than those in aseptic loosening group: the median serum PCT levels (interquartile range: IQR) were 0.33 ng/mL (0.08-2.79 ng/mL) in PJI group compared with 0.04 ng/mL (0.03-0.06 ng/mL), and the median SF-PCT levels (IQR) were 0.16 ng/mL (0.12-0.26 ng/mL) in PJI group compared with 0.00 (0.00-0.00 ng/mL) (p<0.001 both) (Fig 1). SF-PCT, with a cut-off level as 0.08 ng/mL, had a AUC of 0.87, a sensitivity of 90.0% and a specificity of 83.3%, and a negative likelihood ratio (LR-) of 0.12. Whereas serum PCT, with a standard cut-off level as 0.5 ng/mL, had a AUC of 0.70, a sensitivity of 40.0% and a specificity of 100.0%, and a LR- of 0.60. (Fig 2-3)

Conclusion

SF-PCT appears to be a reliable test and could be useful as an alternative indicator or in combination for the diagnosis of PJI.

Figures

	PJI (n=20)	Aseptic loosening (n=12)	p-value
Sinus tract presence◎	0 (0%)	0 (0%)	1.00
Synovial fluid culture◎	13 (65%)	0 (0%)	<0.001
Tissue culture◎	12 (60%)	0 (0%)	<0.001
Serum markers			
ESR△▽	81 ± 27	18.5 (12.5-36.5)	<0.001
CRP△	149 ± 98	2.9 ± 2.5	<0.001
Serum PCT▽	0.33 (0.08 - 2.79)	0.04 (0.03-0.06)	<0.001
Synovial fluid markers			
Synovial WBC▽△	78920 (3420-335400)	1350 ± 827	<0.001
%Neutrophil △	90.8 ± 6.2	54.9 ± 17.2	<0.001
Synovial PCT▽	0.16 (0.12 - 0.26)	0.00 (0.00-0.00)	<0.001

◎; value presented as number of case (percentage), △; value presented as mean standard deviation, ▽; value presented as median (interquartile range)

Figure 1

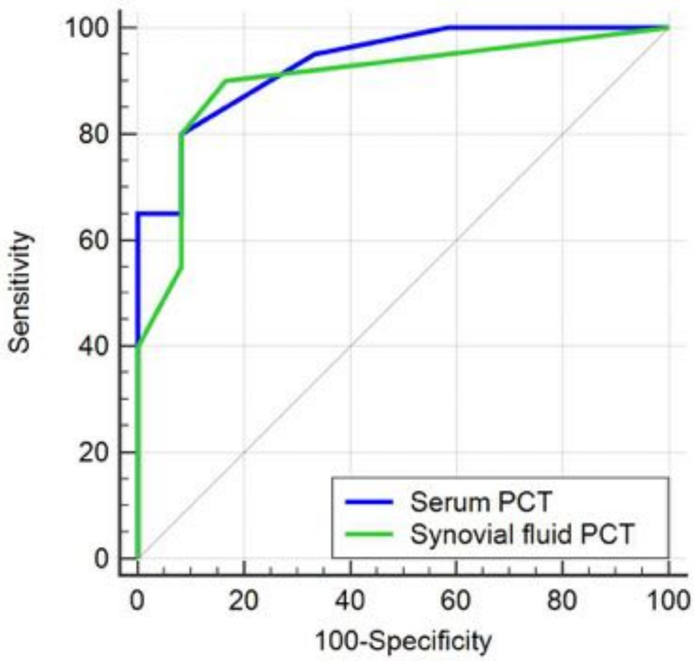

Figure 2

	Sensitivity	Specificity	AUC	LR+	LR-
Serum PCT (ng/mL)					
0.1	65.0 (40.8-84.6)	91.7 (61.5-99.8)	0.78 (0.60-0.91)	7.80 (1.16-52.35)	0.38 (0.21-0.71)
0.3	50.0 (27.2-72.8)	100.0 (73.5-100.0)	0.75 (0.57-0.89)	n/a	0.47 (0.29-0.76)
0.5	40.0 (19.1-64.0)	100.0 (73.5-100.0)	0.70 (0.51-0.85)	n/a	0.60 (0.42-0.86)
Synovial fluid PCT (ng/mL)					
0.08	90.0 (68.3-98.8)	83.3 (51.6-97.9)	0.87 (0.70-0.96)	5.40 (1.51-19.30)	0.12 (0.03-0.46)
0.12	80.0 (56.3-94.3)	91.7 (61.5-99.8)	0.86 (0.69-0.96)	9.60 (1.45-63.50)	0.22 (0.09-0.53)
0.16	55.0 (31.5-76.9)	91.7 (61.5-99.8)	0.73 (0.55-0.87)	6.60 (0.97-44.93)	0.49 (0.29-0.82)

AUC; area under curve, LR+; positive likelihood ratio, LR-; negative likelihood ratio, PCT; procalcitonin

Figure 3

CRP (C Reactive Protein) Level After Total Knee Replacement in Indian Population- Does It Follow Anglo-Saxon Trend ?

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INTRODUCTION : This study is to determine the response of CRP after TKR surgery , both unilateral and simultaneous bilateral TKR . According to the previously published literature from North America and Europe CRP value peaks on the 1st and 2nd post-operative day and the gradually comes down to normal by 6-8 weeks post-operatively.

AIM : To determine the trend of CRP in Indian patients undergoing TKR, both unilateral and simultaneous bilateral TKR, To see whether it follows the trend in North American and European population and to determine whether there is a difference in the CPR pattern in unilateral versus simultaneous bilateral TKR patient

MATERIAL & METHODS : Twenty six patients were included in this study . 13 patients each had unilateral TKR and simultaneous bilateral TKR. All the patients were operated by a single surgeon and assistant. Patients who had Rheumatoid arthritis and post operative adverse events like urinary tract infection were excluded from this study. All 26 patients were female patients and the mean age in the unilateral group was 67 years and in the simultaneous bilateral TKR group was 73 years. CRP levels were measured pre- operatively on 2nd day and 8 weeks.

TKR was performed in a standard fashion. Both the groups received standard pre and post operative antibiotic prophylaxis. All patients received a posterior stabilized knee implant (Maxx Freedom Knee).

RESULTS : In both the groups CRP level shot up on the 2nd post-operative day. Although the rise in CRP level was significantly higher in the simultaneous bilateral TKR group as against the unilateral TKR group. This difference was statistically significant. The CRP level came back to normal in about 39% of unilateral TKR patients at 8 weeks post operatively, while in majority (12 out of 13) of bilateral simultaneous TKR patient it was still elevated at 8 weeks post-op and had not come to normal.

DISCUSSION : Macrophages are the important in the development of acute phase response namely CRP. The macrophages are present in the bone and bone marrow and less often in the skeletal muscle. The bone and bone marrow injury happening while performing TKR is responsible for elevation of CRP. Various North-American and European studies have shown that the CRP level increases significantly on the 1st postoperative day and the decreases from a peak on the 2nd postoperative day, attaining normal value at 6 to 8 weeks after operation. The result of our study are in variance to this published literature. Nearly 39% of our unilateral TKR patients and majority all of our simultaneous bilateral TKR patients did not achieve a normal CRP at 8 weeks after operation. These findings are significant as CRP is often used as a very sensitive indicator of post operative joint infection. Hence we conclude that the Indian TKR patients take longer time for the CRP values to become normal and the published literature regarding the normal levels of CRP In Unilateral TKR should not be extrapolated to simultaneous bilateral TKR group

#5801

Seasonal Relationship of Prosthetic Joint Infection Following Primary Total Joint Arthroplasty in a Sub-Tropical Climate

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Introduction:

There are a number of recognized risk factors for developing prosthetic joint infections (PJI). However, there is a paucity of evidence on the relationship between climate, seasonality and PJI. Previous studies have found increases in surgical sight infections in summer months, however specific climate data was not investigated. This study aims to specifically examine the relationship between the average temperature and humidity at the time of total joint arthroplasty (TJA) and the development of PJI within 12-months in a sub-tropical climate on the North American continent.

Methods:

After IRB approval, all patients undergoing primary TJA (hip or knee) at a single institution in a sub-tropical climate location from 2012 – 2015 were reviewed. Inclusion criteria included primary procedure and a minimum of 1-year follow-up, revision procedures were excluded. Patient demographic data were obtained. The monthly average high and low temperatures, average humidity, and average precipitation were obtained. The primary endpoint was PJI requiring a second surgery within 12-months of index procedure.

Results:

A total of 6520 TJAs met inclusion criteria, with 57 PJIs requiring a second surgery within 1-year (0.87%). Although August had the highest incidence of PJIs (1.35%), this was not significant (p=0.8996). August also was the hottest (91° F), the most humid (79%), and had the most average precipitation (5.98”), however these were not significant contributors to the incidence of PJI (p=0.5001, p=0.5000, and p=0.5002, respectively). Rate of PJI was found to poorly correlate with average high temperature (R^2=-0.080), average low temperature (R^2=-0.070), average precipitation (R^2=-0.027), and average humidity (R^2=0.000975). When stratified by season, there was no correlation between PJI and season (p=0.7189).

Conclusion:

There is no association between temperature, humidity, and development of prosthetic joint infection in a North American Sub-Tropical Climate. Surgeons can use this information to council patients when planning surgery.

#5640

Obesity Increases Risk of Infection in Revision Total Hip Arthroplasty

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Aim: The aim of this study is to evaluate if obesity negatively affects: (1) complication rate, (2) reoperation and revision rate and (3) functional outcome (based on patient reported outcome measures, PROMs) in revision total hip arthroplasty (rTHA). To our knowledge this is the only recent study to prospectively review these three aspects in what might be considered challenging rTHA.

*Methods:*444 rTHAs (cup, stem, both, n= 265, 57, 122 respectively), performed in a specialized high-volume orthopaedic center from 2013 to 2015, were prospectively followed. Complications and Oxford Hip Score (OHS) were evaluated at 4 months, 1 year and 2 years. Thirtyfour patients had a BMI >35 kg/m2 (obese), of which thirteen patients with a BMI >40 kg/m2 (morbidly obese).

Results: Infection following rTHA was more common inobese patients (8/34: 24%) and in morbidly obese patients (5/13: 38%) than in non-obese patients (15/410: 4%; p's < 0.001). No differences between obese and non-obese groups for other complications were observed (aseptic loosening, dislocation, periprosthetic fractures, thromboembolic events). Reoperation and revision rates were similar overall (p = 0.067 / 0.303 respectively) and due to infection (p = 0.469 / 0.879 respectively) for obese and non-obese groups. Scores on the OHS improved from 42 ±13 at baseline to 27±12 at 1 and 2 year follow-up (p < 0.001). Obese patients had overall poorer OHS scores than non-obese patients (p < 0.001), but improvement of OHS did not differ between obese and non-obese patients (p = 0.198).

Conclusion: Obesity is associated with an increased risk of infection following revision THA. Patients with high BMI should be counselled appropriately before surgery.

#6136

Changes in Invasiveness and Latent Infection Rate Associated With Switching in Approach of Total Hip Replacement

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Purpose: Various approaches have been reported for the total hip replacement (THR). In recent years, a muscle sparing approach with low postoperative muscle weakness and low dislocation risk has been frequently selected. However, such surgery has a learning curve. Thus, at the time of switching from the conventional approach to such approaches, invasion or infection risk may increase with the operation time extension. The purpose of this study is to clarify the change of invasiveness or latent infection rate with the change in approach in order to select the cases safely at the beginning of introducing a new approach in THR.

Methods: In facility A, THR was performed with Dall's approach (Dall), but 1 surgeon changed Dall to anterolateral modified Watson-Jones approach (OCM) and another surgeon changed Dall to direct anterior approach (DAA). In facility B, all 3 surgeons changed posterolateral (PL) approach to OCM. The subjects are 150 cases in total, including the each last 25 cases operated with the conventional approach and the each first 25 cases operated with a new approach (Dall to OCM: 25 + 25, Dall to DAA: 25 + 25, PL to OCM: 25 +25 cases). And, differences in operative time, intraoperative bleeding volume, postoperative hospital stay, and postoperative hemoglobin, white blood cell count, lymphocyte count, creatine kinase (CK), C-reactive protein (CRP) were investigated.

Results: The average age of subjects was 64 years (31-87 years old), and there were 27 male subjects and 123 female subjects. In the change from Dall to OCM, only the postoperative hospital stay decreased significantly. In the change from Dall to DAA, the length of hospital stay and postoperative CRP significantly decreased, but the intraoperative bleeding volume increased.In the change from PL to OCM, the operation time, postoperative CRP and CK decreased, but postoperative Hb decreased. Cases with lymphocytes less than 1000/µL or less than 10% after surgery on day 4 are latent infection cases, and in such cases the operation time was significantly longer, the postoperative Hb was significantly lower, and the postoperative CK was significantly higher. However, such cases were not significantly increased by the change of operation approach.

Conclusion: Introduction of the muscle sparing approach improved many items on surgical invasion, but some items deteriorated especially at the beginning of a new approach.In the early stages of introduction of the new approach, choosing cases without obesity and without lots of muscle volume may reduce latent infection.

#5778

An Enhanced Understanding of Culture-Negative Periprosthetic Joint Infection With Next Generation Sequencing

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Background: Recent reports demonstrate that Next Generation Sequencing (NGS) facilitates pathogen identification in the context of culture-negative PJI; however the clinical relevance of the polymicrobial genomic signal often generated remains unknown. This study was conceived to explore: (1) the ability of NGS to identify pathogens in culture-negative PJI; and (2) determine whether organisms detected by NGS, as part of a prospective observational study, had any role in later failure of patients undergoing surgical treatment for PJI.

Methods: In this prospective study samples were collected in 238 consecutive patients undergoing revision total hip and knee arthroplasties. Of these 83 patients (34.9%) had PJI, as determined using the Musculoskeletal Infection Society (MSIS) criteria, and of these 20 were culture-negative (CN-PJI). Synovial fluid, deep tissue and swabs were obtained at the time of surgery and sent for NGS and culture/MALDI-TOF. Patients undergoing reimplantation were excluded. Treatment failure was assessed using the previously described Delphi criteria. In cases of re-operation, organisms present were confirmed by culture and MALDI-TOF. Concordance of the infecting pathogen(s) at failure with the NGS analysis at the initial stage CN-PJI procedure was determined.

Results: Twenty cases of culture-negative PJI were identified (Figure 1). CNPJI rate in our samples was 24%. NGS was positive in 18 cases. Two cases were both culture and NGS negative. Eight CN-PJIs (8/20; 40%) failed by re-operation with infection recurrence confirmed on culture. In 7 of these 8 cases (88%), the organism at failure was present on NGS at the time of the initial CN-PJI procedure. The remaining case failed with a new organism, via likely hematogenous seeding from an inter-current infection (Figure 2). NGS detected several organisms in CN-PJI cases (Figure 3).

Discussion: CN-PJI is often associated with polymicrobial genomic organism profile. Furthermore, most of the failures by infection recurrence were due to an organism previously detected by NGS. Our findings suggest some cases of PJI may be polymicrobial and escape detection using conventional culture. Further multi-institutional work with larger numbers and longer clinical follow-up is required for validation.

Figures

Figure 1: Study flowchart detailing the procurement of consecutive patient samples.
Culture(+) = culture-positive, culture(-) = culture-negative, and NGS(+) = next-generation sequencing-positive.

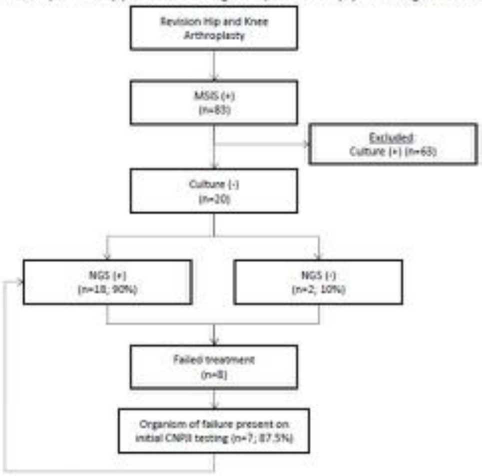

Figure 1

Figure 2: Table showing concordance between organisms identified at failure vs. NGS signal at initial revision procedure.

Patient	Culture at treatment failure (two positive cultures; MALDI confirmed)	Organism present at initial NGS?	% abundance of the organism on initial CN-PJI NGS report	Number of different organism species per case (polymicrobial NGS detection)
1	Staphylococcus epidermidis	Yes	11.18	3
	Coagulase negative staphylococcus	Yes	12.97	
	Pseudomonas aeruginosa	Yes	0.38	
2	Staphylococcus epidermidis	Yes	11.18	14
	Coagulase negative staphylococcus	Yes	12.97	
	Pseudomonas aeruginosa	Yes	0.38	
3	Staphylococcus epidermidis	Yes	11.42	18
4	Staphylococcus epidermidis	Yes	32.57	9
	Pseudomonas aeruginosa	Yes	0.25	
5	Staphylococcus epidermidis	Yes	21.95	9
6	Staphylococcus epidermidis	No	-	1
	Pseudomonas aeruginosa	No	-	
7	Staph aureus (methicillin resistant)	Yes	0.00	5
8	Staphylococcus epidermidis	Yes	28.66	9

Figure 2

Figure 3: Pie chart showing the relative abundance of different genera detection within CN-PJI cohort (n=20)

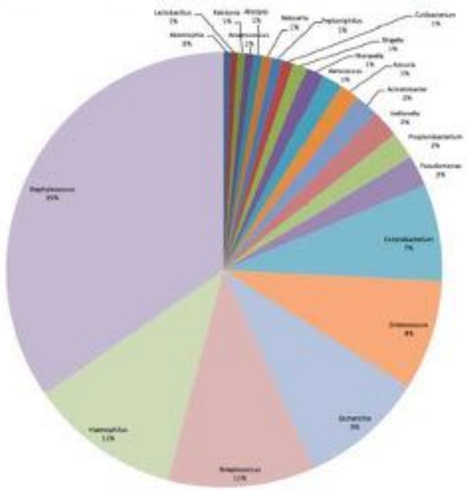

Figure 3

#5538

Long-Term Clinical Outcome of Two-Stage Revision Surgery for Infected Hip Arthroplasty Using Cement Spacer: Culture Negative Versus Culture Positive

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Introduction: Periprosthetic joint infection (PJI) is a terrible complication after hip arthroplasty. Clinical feature of culture-negative PJI (CN-PJI) has not been well studied till now. In our study, we retrospectively analyzed long-term clinical results after two-stage revision arthroplasty using an antibiotic-impregnated cement spacer for CN-PJI. The purpose of this study is to investigate the clinical features and prognosis of CN-PJI after hip arthroplasty and to compare these with those of culture-positive PJI (CP-PJI). Methods: We retrospectively reviewed 15 CN-PJI cases and 70 CP-PJI cases following hip arthroplasty. The average follow-up period was 7.4 years (5-11.7 years). The demographics, laboratory findings, the time interval between antibiotic-impregnated cement spacer insertion and revision arthroplasty, and recurrence of infection were analyzed. Results: The CN-PJI group showed a significantly higher incidence of prior antibiotic use ($p = 0.004$) and lower serum C-reactive protein (CRP) level ($p = 0.001$) than the CP-PJI group. Normalized time interval of CRP level in CN-PJI was shorter than that of CP-PJI group. The mean interval time for two-stage exchange arthroplasty was also significantly lower ($p = 0.049$) in the CN-PJI group than the CP-PJI group. There was no case of treatment failure or major complication in CN-PJI group. Conclusion: The CN-PJI group after total hip arthroplasty could be treated successfully by two-stage exchange arthroplasty without any complications. Clinical course and prognosis of CN-PJI group was also better compared with that of CP-PJI group. Therefore, culture negativity of PJI cannot be always a poor prognostic factor for the treatment

#5973

A Comprehensive Review of the Use of Silver Coated Megaprostheses for Infection Control Following Tumor Resection

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INTRODUCTION

Post-operative infection control following tumor resection and megaprosthetic reconstruction is of paramount importance for success of the treatment strategy and longevity of the prosthetic composite. Silver coating is an innovative development in the prevention of post-operative infection. To date, there is not a complete summary of the use of silver coating on megaprostheses. The purpose of this review is to summarize;

(1) the current knowledge of the use of silver coated prostheses for infection control,

(2) concerns with ion release and toxicity,

(3) present current published results and

(4) discuss current regulatory issues both domestically (USA) and worldwide.

METHODS

We report the results of a single surgeon case series and comprehensive literature review of the technology of silver coating application to prostheses and the published clinical results of the success of decreasing the incidence of post-operative infection following tumor resection and limb salvage.

DISCUSSION AND CONCLUSION

The potential for the use and success of silver coated megaprostheses following tumor resection is great importance and, based on our review shows significance in the decrease of post-operative infection without adverse issues of silver toxicity (Argyria). While the majority of the regulatory world has allowed the routine use of silver coated megaprostheses for infection control, there still exists a few regulatory panels, including the US-FDA, that have yet to approve the routine use of silver coated megaprostheses for infection control following tumor resection and limb salvage.

Outcome of the Treatment of Knee Prosthetic Joint Infection

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ã€Introductionã€'Prosthetic joint infection(PJI) is one of the most serious complication after total knee arthroplasty(TKA) and is usually difficult to treat. Treatment Strategies for PJI are well discussed, however, there are still controversial options for it. Here, we report outcome of treatment for knee PJIs in our institute.

ã€Materialsã€'We experienced 42 cases for infection after TKA between January 2006 and December 2016 (Men:18 cases,females:24 cases). Average age was 71.5 ± 9.1 years old (range, 45 to 87 years old). Twenty-six cases (62%) were treated with open debridement and tibial insert exchange (Debridement group). Two-stage revision TKA was performed in fourteen cases (33%). One resection arthroplasty and one arthrodesis operation were also performed (2%). A total of 16 cases were regarded as revision group. In both groups, the causative bacteria, the period from the primary TKA to onset, the classification of Segawa, and the antibiotic used were investigated and compared.

ã€Resultsã€'The period from the initial surgery to the onset of infection was 42.7 months (10 days to 28 years). In debridement group, it was 41.7 ± 63 months (range,10days to 17years). In revision group, it was 43.5 ± 89 months (range,15days to28 years). No significant difference was recognized. Segawa's classification Type1 (positive intraoperative culture) was no case, Type2 (early postoprative infection) was 17 cases, Type3 (acute hematogenous) was 17 cases, Type4 (late chronic) was 8 cases. Type 4 has a significantly lower component retaining rate (P = 0.0322). The causative organisms were methicillin resistant staphylococcus epidermidis(MRSE) 9 cases, methicillin resistant staphylococcus aureus (MRSA) 6 cases, methicillin susceptible staphylococcus aureus(MSSA) 6 cases, methicillin susceptible staphylococcus epidermidis(MSSE) 2 cases, Dysgalactiae 4 cases, E. coli 3 cases, others 11cases. The retaining rate of resistant bacteria (MRSA+MRSE) and nonresistant bacteria (MSSA+MSSE) were not significantly different. The retaining rate of Staphylococcus epidermidis (MRSE+MSSE) was significantly higher than it of Staphylococcus aureus (MRSA+MSSA) (p=0.0221).

ã€Discussionã€'Debridement and exchange of the tibial insert has been recommended as a treatment for PJI in patients who have a well-fixed prosthesis. In the cases of Segawa's classification Type4, it was difficult to retain the component. Before becoming chronic osteomyelitis, early treatment intervention is important. However, symptoms may be slight or bacterial cultures may become false negatives, therefore early diagnosis is difficult in PJI. In the cases of S. epidermidis infection, it seems that diagnosis is delayed and transition to chronic infection is easy because symptoms are relatively slight. The PJI still remains a difficult problem in very complex patients.

#6206

Debridement, Antibiotics and Implant Retention (DAIR) Following Total Hip and Knee Replacements

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OBJECTIVE:

Debridement, Antibiotics and Implant Retention (DAIR) procedure is well established for Prosthetic Joint Infection (PJI) in acute setting after total hip and knee replacements. We present our perspective of DAIR in a relatively a small cohort following hip and knee replacements in a District General Hospital (DGH) in United Kingdom, where we delivered comparable results to leading tertiary centres in short to mid-term followup.

METHODS:

We undertook a retrospective study involving 14 patients, who underwent DAIR in our DGH between August 2012 and December 2015. Patient cohort included primary, complex primary and revision hip and knee replacements. Multiple samples were taken intraoperatively for cultures and histology. Microbiological support was provided by a Microbiologist with interest in musculoskeletal infections.

RESULTS:

14 patients [9 males, 5 females; age 62 -78 years (Mean 70.7); BMI 22- 44.2 (Mean 33.8)] with multiple comorbidities underwent DAIR procedure within 3 weeks of onset of symptoms, *(although the time from index surgery ranged from 15 days to 58 months.).* Patient selection was made by two Hip surgeons. 12 out of 14 grew positive cultures with two growing Vancomycin resistant Enterococcus. IV antibiotics were stated after samples intraoperatively and continued in six patients after discharge using (OPAT), while 8 were discharged with oral antibiotics. One patient died in immediate post operative period due to generalised sepsis. Another patient died of myocardial infarction 2 years after DAIR. 12 (85.7%) patients are doing well with regular followup (Mean 20 months) in clinics.

CONCLUSIONS:

With good patient selection, DAIR is a far simpler solution and a safe and reproducible surgical option in PJI in hip and knee replacements compared to one or two stage Revisions with the implications. But published Data in contemporary literature is predominantly from specialised centres. Our small series provides a perspective of early to mid term results of DAIR from a DGH.

#5524

Hand-Made Articulating Cement Spacers in Two Stage Revision for Infected Total Hip Arthroplasty: A Prospective Cohort Study

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Introduction: Periprosthetic joint infection (PJI) is a serious problem and requires great effort and cost for its treatment. Treatment options may vary from resection arthroplasty, retention of prosthesis with debridement, one stage revision and two stage revision with handmade antibiotic impregnated cement spacer or with prefabricated antibiotic loaded cement spacer. Two stage revision remains the gold standard for the treatment of periprosthetic joint infection after Total Hip Arthroplasty (THA). This study was aimed to find the efficacy and cost effectiveness of handmade antibiotic impregnated articulating cement spacer over commercially available prefabricated antibiotic loaded cement spacer for the treatment of deep PJI of hip prosthesis and to evaluate its functional outcome.

Material and methods: A total of 23 PJI patients were enrolled in this prospective cohort study. In the two stages of revision, the first stage consisted of thorough debridement, implant removal and implantation of handmade articulating antibiotic impregnated cement spacer. The second stage surgery consisted of removal of cement spacer, thorough debridement and implantation of new prosthesis. All patients were followed for a period of 24 months.

Results: A total of 23 patients (15 males and 8 females) underwent two stage revision arthroplasty for chronic periprosthetic joint infection. The mean age of the patient was 57 years. The handmade antibiotic impregnated cement spacer was retained for 16- 20 weeks. Common organism observed was coagulase negative staphylococci followed by Staphylococcus aureus. After an average follow up of 2 years, 20 patients with PJI remained clinically free of infection. In 2 patients there was recurrence of infection.

Conclusion: we conclude that two stage revision by hand made cement spacer is successful in eradication of infection with satisfactory functional outcome. Furthermore, these handmade cement spacer are cost effective and their efficacy may be comparable to commercially available prefabricated spacer.

#5974

Two to Eight Year Results of the Use of Megaprosthesis for Infected End-Stage Revision Cases

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Introduction:

The use of a megaprosthesis device is most valuable when presented with extreme bone loss due to infection and/or multiple revisions. In the patient presenting with a chronically infected limb or end-stage revision, these devices are a valuable tool and an alternative to amputation.

Purpose:

The purpose of this study is to report the 2 to 8-year results of the use of megaprosthetic devices by a single surgeon.

Materials and Methods:

A full retrospective clinical and radiographic review of the senior author's records was performed for cases between January, 2007 and May, 2013 in which megaprosthetic devices were used. Patients were divided into four groups by megaprosthesic device used:

1) Hip & Proximal Femur n=21

2) Knee &DistalFemur n=26

3) TotalFemur n=13

4) Fusion n=25

Results:

There was a total of 85 patients reviewed and all patients had a minimum of two-years follow-up (average: 4.4 years). Of the 85 patients, 80 (94%) had significant co-morbidities and 75 had multiple comorbidities (88%). The most common

comorbidities included obesity (BMI>34) and diabetes. There were 18 (21%) of 85 cases that were deemed "failures" and included 12 (14%) for recurrent infection at an average of 5-years (range: 2.3 - 8.0 years), in which 8 cases presented with a different bacterium than at the time of megaprosthetic implantation. Overall, there were 3 (3.5%) of the cases that went on to amputation.

Discussion and Conclusion:

The use of a megaprosthetic device when faced with the chronically infected patient following multiple revisions and subsequent extensive bone loss is a strategic option for limb reconstrucion. Various authors report megaprosthetic failure rates approaching 80%. We report a large series of intermediate-term follow-up cases of megaprosthetic use with an overall failure rate of 21%. The authors conclude that in the chronically infected, end- stage revision patient, the use of a megaprosthetic device is a viable option for the restoration of limited limb function and patient independence with moderate to good success as an alternative to amputation.

#5979

The Chronic Salvage Patient: When Is Enough, Enough?

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Introduction:

Complex limb-sparing surgery is becoming more common as analternative to permanent fusion or the finality of amputation.These complex cases are presenting significant problemsincluding multiple recurrent infections over time, multiple comorbidities, multiple previous surgeries and inadequate softtissue. The purpose of this study is to determine why certainpatients fail salvage procedures; are there patients we shouldnot be operating on and is there a way to determine that?

Methods:

We reviewed 91 patients who we have treated formegaprosthetic infection. Patients were distributed equally bygender (46 each). The average age megaprostheticreconstruction 61.2 years ±13.4 (range:15.5 to 87.9 years) andthe average BMI was 36.7 ±18.6 (range: 20 to 66). This patientcohort presented at surgery with an average of 3.7 ±1.7 majorcomorbidities (range: 0 to 7) and had an average of 6.6 ±5.5(range: 2 to 27) previous surgeries on the indicated limb.

Results:

The average time to post-salvage follow-up was 4.3 years ±3.2(range: 1 to 18 years). Following the salvage reconstruction, thispatient cohort required an additional average of 3.2±2.9surgeries (range: 0 to 17). Of the post salvage surgeries 30(39%) were for I&D, 18 (24%) were for falls, and 11 (14%) wererelated to prosthetic loosening. Full ambulation was observed in23 (27%) patients, ambulation requiring aids in 59 (68%) and 4(5%) were non-ambulatory. Fourteen patient requiredsubsequent permanent fusion to salvage the indicated limb and3 patients went on to amputation.

Discussion and Conclusion:

The "Severe Risk" group includes patients that have undergoneradiation treatment, renal dialysis, no muscle coverage, > 5previous surgeries or psychiatric issues that would inhibitcompliance. Patients at "Increased Risk" includes a combinationof 3 or more medical comorbidities. We identified a third of ourpatients in which a permanent fusion or amputation shouldhave been performed early; one third of our patients may havehad better outcomes with alternative treatments such as silvercoated components; and one third were worth the risk becausethey were healthier and presented with fewer comorbidities.From this review, we must ask ourselves:

1) How many surgeriesare too many surgeries?

2) How much money should we bespending to achieve these endpoints?

3) Are there patients weshould not be performing these surgeries on?

4) Is it worth thesalvage for these patients?

#5526

3d Printed Acetabular Components for Complex Revision Arthroplasty. a Case Series.

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Introduction

Revision total hip arthroplasty is a complex procedure and becoming more common. Acetabular implant loosening or fracture has previously been treated with a cup and cage construct. Recent studies have shown significant failure rates with Cup Cage constructs in more complex 3B and 3C Acetabular revisions. As a result the use of 3D printed custom made acetabular components has become more common.

Method

We present 5 cases with severe acetabular bone loss that were treated with 3D printed acetabular components. The components were manufactured by OSSIS medical in New Zealand. The patient’s original femoral stem was retained in all cases. Pre operatively the implant design was approved by the arthroplasty team prior to final manufacture. Implants were provided with a sterilisable model used intraoperatively for reference.

Results

Five cases of 3D printed acetabular implants have been used locally for complex revision total hip arthroplasty with no immediate intraoperative or postoperative complications. Follow up of 1 – 5 years. One patient fell, five years post operatively. Sustaining a periprosthetic femur fracture requiring plate fixation, however, the acetabular component remained stable. No patient has undergone surgery for any failure of the acetabular component.

Conclusions

This study shows 3D printed custom acetabular implants are efficient and effective in our hands. Early results from the design team suggest improved results compared to TM cup / cage systems. None of the implants have failed for any reason to date.

#6087

PSI for One-Stage and Two-Stages of Revision TKA Using CCK and Hinged Implants

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In this work, we present a case of native pelvic discontinuity, which has been managed with computer-assisted surgery using patient-specific instruments and customized implants. Bone scan with Gallium confirmed isolated right hip infection which was done before debridement (Figures 1, 2). He eventually had removal of metalwork on the right side with femoral head excision and insertion of cement spacer. A further debridement was performed and articulated cement spacer was inserted along with a Mexican-hat spacer. This technique (Mexican-hat) was advocated by the first author and has been used for acetabular infection when the medical wall is broken and infection is spread to the pelvis. It is also used when the antibiotic needed is not included in the articulating spacer. The second stage reconstruction was planned using CAD/CAM technology with a custom-designed triflange cup construct from Mobelife, Sweden. Preoperative CT scans with 3D formatting were obtained to plan the customized implant. The design was finalized using 3D printing technology. A total of 17 screws were planned in angles (trajectory) intended to target regions of reasonable bone stock as noted on the CT scans and according to a finite-element analysis. The flanges were designed with screw holes so that trajectory of the cup fixation screws would not interfere with placement of flange screws. The screws were planned to be inserted into the ilium, ischium and pubis and inside the cup. The prosthesis was implanted as per preoperative plan with guided screw placement. The length and diameter of all screws were also predefined based on the scans. During surgery, there was no evidence of infection. The spacer was removed along with the Mexican hat. Routine procedure was done for femoral implantation: positioning of the cup and placement of the screws were done smoothly using PSI as planned preoperatively. After two years, there was no recurrence of infection or loosening (Figures 3, 4). The results suggest that custom triflange cup manufactured with computer-assisted technology for management of native/infected pelvic discontinuity could be a viable treatment modality.

Figures

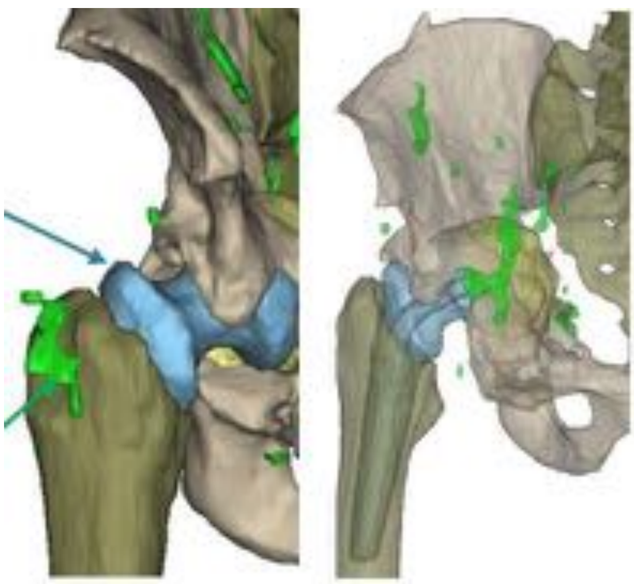

Figure 1

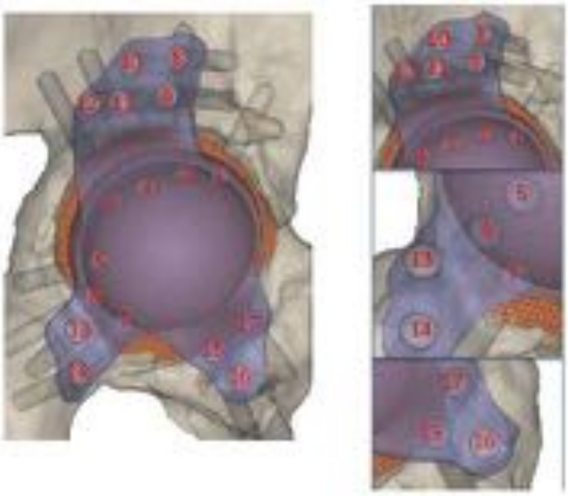

Figure 2

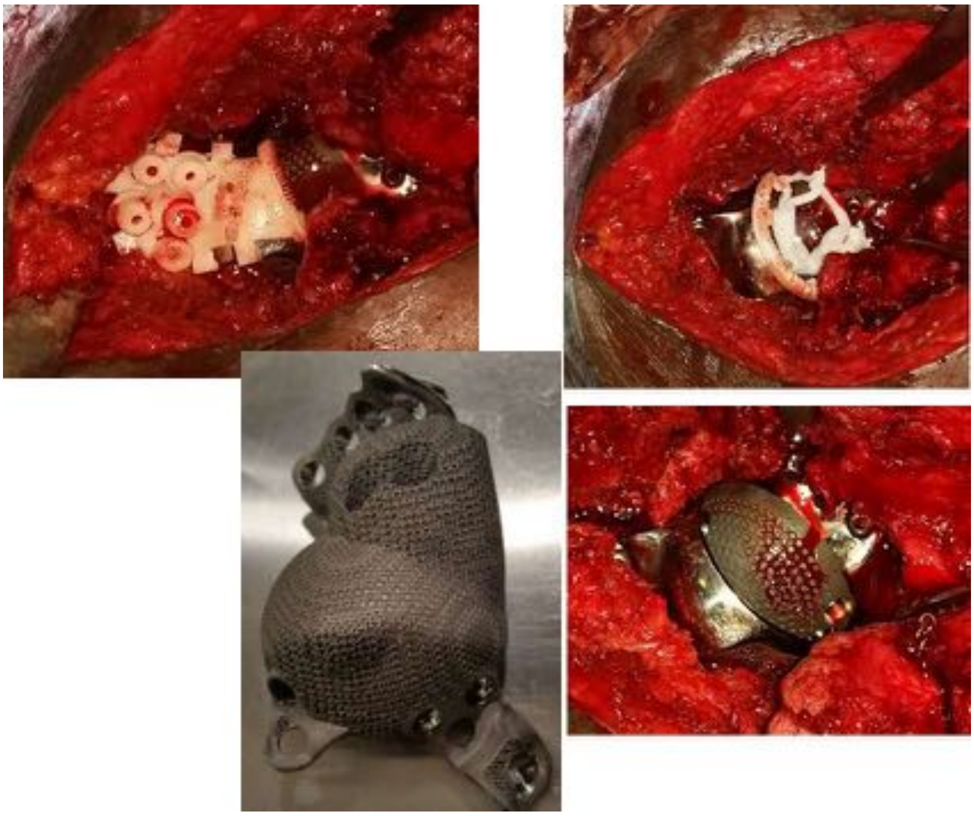

Figure 3

Figure 4

#5629

Cup Migration After Acetabular Revision Surgery With Impaction Bone Grafting and a Cemented Cup in Large Bone Defects

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Introduction: Impaction bone grafting (IBG) is a reliable technique for acetabular revision surgery with large segmental defects. However, bone graft resorption and cup migration are some of the limitations of this tecnique. We assess frequency and outcome of these complications in a large acetabular IBG series.

Patients and Methods: We analysed 330 consecutive hips that received acetabular IBG and a cemented cup in revision surgery with large bone defects (Paprosky types 3A and 3B). Fresh-frozen femoral head allograft was morselized manually. The mean follow-up was 17 years (3-26). All data were prospectively collected. Kaplan-Meier survivorship analysis was performed. Changes in different paremeters regarding cup position were assessed pre- and postoperatively and at the follow-up controls. Only variations greater than 5º and 3 mm were considered.

Results: The mean Harris Hip Score improved from 48.3 ± 8.5 to 84.6 ± 12.8 at final follow-up. The radiological analysis showed cup migration in 42 hips. The mean appearance time was 4.3 years (range, 1-25). Migration was progressive and painful in 27 hips (67.5%) requiring cup revision. Lateral mesh was more frequently associated with migrated cups (p=0.034). Cup tilt was found in 37 out 42 migrated cups, however cranial migration was more frequent in progressive migrated cups (p=0.02). There were 34 re-revisions, 27 due to aseptic cup loosening, 6 due to dislocation and one due to infection. The survival rate for any cause at 16 years was 81.2% (95% Confidence Interval (CI): 74.0 to 88.4) and for aseptic cup loosening was 83.4% (95% CI: 76.2-90.6). In all surviving hips trabecular incorporation was observed without radiolucent lines.

Conclusions: IBG continues to be a reliable technique for large defects in acetabular revision surgery. Bone graft resorption and cup migration was not frequent in this large series and one-third of cases were not progressive. Cup migration was more frequent in cases with a segmental roof defect in which a lateral mesh was used.

#5639

Reconstruction of Severe Superior Acetabular Bone Defects in Revision Total Hip Arthroplasty With Superior Extended Fixation Using Porous Metal Augments

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Background: Severe, superior acetabular bone defects are one of the most challenging aspects to revision total hip arthroplasty. In this study, a new concept of “superior extended fixation” is proposed using porous metal augments. Superior extended fixation is defined as fixation that is 2 cm superior to the superior edge of the acetabulum, which is further classified into intracavitary and extracavitary fixation. It was hypothesized that the use of superior extended fixation would improve the position of the center of rotation in patients with massive superior acetabular bone defects, and achieve satisfactory clinical outcomes.

Methods: Twenty eight revision total hip arthroplasty patients were retrospectively reviewed who underwent reconstruction with the concept of superior extended fixation using porous metal augments from January 2014 to October 2016 in our hospital. There were 11 patients reconstructed with extracavitary extended fixation, and 17 patients with intracavitary extended fixation. Patients were assessed using the Harris Hip Score (HHS) and the Western Ontario and McMaster Universities Osteoarthritis Index score (WOMAC). In addition, radiographs were assessed and patient reported satisfaction were collected. The horizontal and vertical location of center of rotation (COR), as well as cup abduction and anteversion, were measured on radiographs.

Results: At an average follow-up of 28 month (range 18 – 52 month), the mean HHS and WOMAC score improved from 42.3 (range 25.0 - 60.0) and 74.8 (range 62.3 – 91.0), respectively, preoperatively to 80.5 (range 45.0 - 97.0 and 24.4 (range 14.6 – 32.2), respectively, postoperatively ($p < 0.001$). The average postoperative horizontal and vertical locations of the COR from the interteardrop line were 31.5 mm (range 15.1 – 45.7 mm) and 23.1 mm (range 1.7 – 42.7 mm), respectively, which were significantly improved from the preoperative measurements ($p < 0.001$). There was one (3.6 %) patient who was dissatisfied with their outcome due to periprosthetic joint infection.

Conclusion: Our findings indicate that extracavitary and intracavitary superior extended fixation with porous metal augments and cementless cups are effective in reconstructing severe superior acetabular bone defects with promising short-term outcomes.

Figures

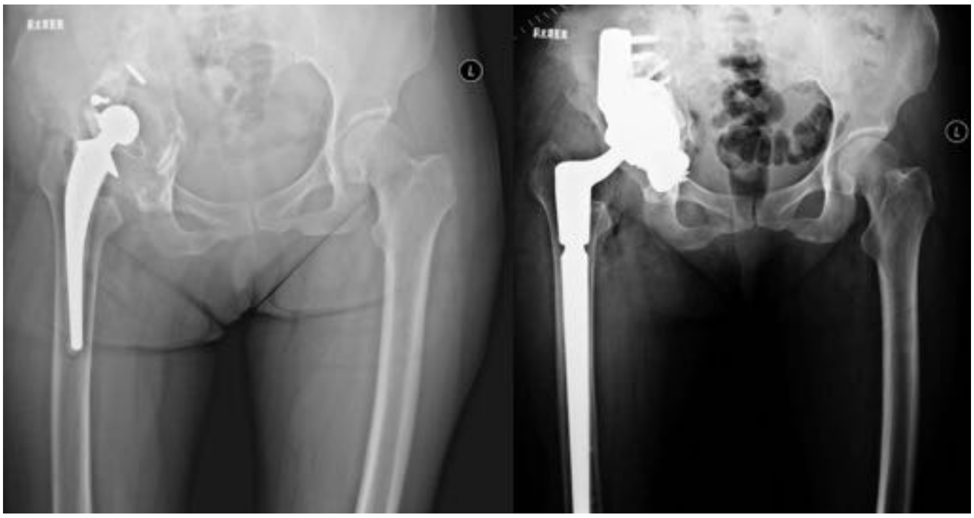
Figure 1

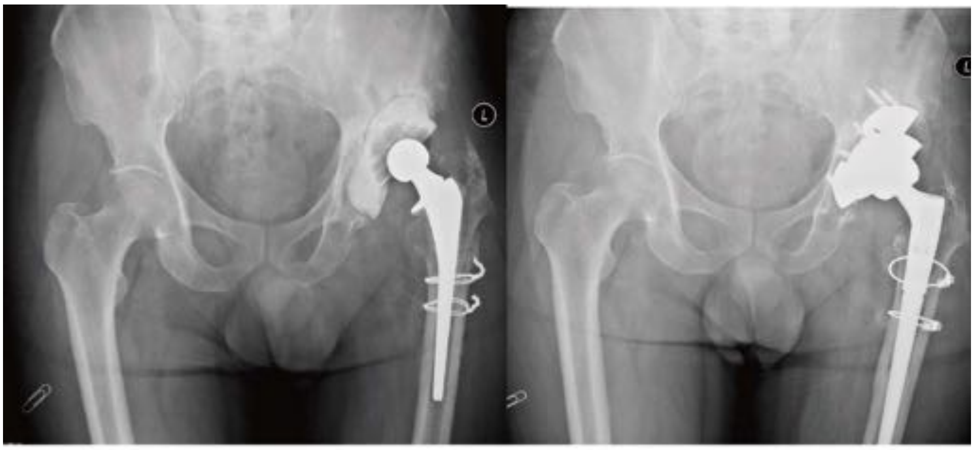
Figure 2


Figure 3

#5546

A New Custom-Made Porous Titanium Device in Knee Revision Surgery: Early Results and Technical Notes

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Introduction. Bone loss management represents one of the most challenging issues for the orthopaedic surgeon. In most cases, stems, structural allograft, TMcones, and sleeves are adequate to allow optimal implant stability and durable fixation. In selected cases of wide metadiaphyseal bone defects, these devices do not provide proper intraoperative stability. In such scenarios, further steps are needed and include complex modular reconstruction, substitution with megaprosthesis (exposing patients at high risk of early failure) or joint arthrodesis that can yield unacceptable results. The aim of this paper is to present early results obtained with a new custom-made implant for complex metadiaphyseal bone defects management in knee revision surgery. By means of case presentations the authors would highlight the possibilities and technical notes of this novel device in complex knee revision surgery.

Methods. Since2015, 8 custom-made porous titanium devices were implanted for massive bone defect management in 6 knee arthroplasty revision procedures. Five patients were staged revision for periprosthetic joint infection (PJI) and one patient underwent a staged revision for post-traumatic septic arthritis. Main demographic and surgical data were collected. Clinical (Range of Movement [ROM], Knee Society Score [KSS] and Oxford Knee Score [OKS]), radiological findings and complications were recorded at different time points and statistically evaluated. Mean follow up was 19.5 ± 9.6months.

Results. The study group included 4 males and 2 females with a mean age of 63.7 ± 5.5 years and a mean Body Mass Index of 29.3 ± 4.1. Globally, the mean number of previous surgeries was 4.8 ± 2.7. The custom made device was combined with a hinged prosthesis in 5 cases and with a constrained condylar implant in 1 patient. Hybrid fixation was used in all cases. The mean KSS and OKS of the entire population improved significantly from 35.3 ±6.5 and 19.2 ±3.5 preoperatively to 85.8 ±4.0 and 39.3 ±3.1 at the time of last follow-up evaluation ($p<0.01$). The range of motion improved from 46.7 ±9.8 of mean preoperative flexion and 7.8 ±6.8 of mean preoperative flexion contracture to 93.3 ±10.3 and 1.2 ±2.9 respectively ($p<0.01$). Radiological analysis showed no migration or implant loosening. No intraoperative or postoperative complication was recorded. One patient required a prolonged antibiotic therapy for positive culture samples of sonication of the retrieved spacer. No implant mismatch between the preoperative planning and the final implant was reported.

Conclusion. The presented custom-made implant showed promising early clinical and radiological results. In extremely selected cases, this new device can be considered a safe and effective surgical step between “off the shelf” reconstruction implants and knee substitution with a tumor megaprosthesis.Accurate surgical planning and intraoperative management of soft tissues and residual bone stock are of paramount importance.

#6171

In Vitro Wear Analysis of the Constrained Knee Systems

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Objective: Condylar constrained knee (CCK) implants are used to improve the implant stability for patients with excessive collateral ligament damage or with poor posterior stability. Despite the stability benefits, there are concerns that the increased constraint provided by the tibial post will increase the wear and thus eventually resulting in loosening. As per the author's knowledge, there are not many studies that reported *in-vitro* wear of the constrained knee system. Thus the objective of the current study is to determine the wear rates of the constrained knee system and compare it to the threshold of osteolysis and determine if CCK can be safe and durable prostheses based on the wear results.

Methods: In the current study, the wear rates of two different constrained knee systems (Group's A & B) studied. Group A consisted of traditional CCK system where the articulation is symmetrical in both medial and lateral condyles while group B comprised of Medial Pivot CCK system. The femoral components for both groups were from ASTM F75 CoCrMo alloy while the tibial inserts for both groups were composed of GUR 1020 UHMWPE (non-cross linked) that was terminally sterilized by Eto process. Each group consisted of three bearing couples for wear test, and two bearing pairs for the load or control soaks. Before testing, all the inserts soaked in the test lubricant for 48 hours. The soaked inserts were cleaned and weighed after removing from the test lubricant and tested in an AMTI knee wear simulator per ISO 14243-1 protocol. Wear test used a compressive load: 168-2000N, IE torque: 1 Nm external to 6 Nm internal, AP force: 110 N anterior to 265 N posterior, frequency- 1 Hz, lubricant temperature: 37 C. Disassembly, cleaning, gravimetric measurements performed according to ISO 14243-2 protocol. Post wear tests the serum samples were collected and digested per ISO 17853:2011 and later particle characterization performed per ASTM 1877-16.

Results & Discussion: The wear rates generated by Group's A and Group B are: 7. 1 and 6.9 mg/Mc respectively. There is no statistically significant difference in wear rates from both systems (t-test, P-0.89, Minitab) and they are below the osteolytic limit of 80 mm^3 per year (as reported by Oparaugo & colleagues) which is equivalent to 74 mg/Mc. While this threshold is for hip penetration rates, it represents a useful benchmark in the absence of knee-specific data. SEM images revealed globular morphology for wear particles. The mean average particle ferret diameter and equivalent circle diameter for Group A tibial inserts were 1.23 and 1.01 microns while for Group B they are 2.52 microns and a 2.10 microns. The sizes and the morphology of PE particles resulting from this testing were in a similar range to those reported in the literature studies. The results from the current study demonstrate that CCK could be a safe and durable prosthesis.

#5928

Total Knee Arthroplasty Using Only Cementless Component â€“ a Minimum 10 Years Follow-Up

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Introduction:

Cementless Total Knee Replacement (TKR) was introduced to improve the longevity of implant; but has yet to be widely adopted because of reports of higher earlier failures in some series. The cementless TKR design has evolved recently and we have been using cementless component – both femoral and tibial on our patients. The long follow-up for fully TKR has been scarce in the literature. The purpose of this study isto investigate the minimum of ten years clinical and radiographic result of cementless titanium component and cementless tantalum component in primary TKR.

Material & method:

From 2008 to 2010 317 TKR underwent primary total knee with cementless femoral component titanium based (Zimmer Nexgen) and cementless tantalum component monoblock tibial component, The surgery was performed mainly on younger patients - average age was 48 yrs old ranging from 26 yrs old to 62 yrs old. All surgeries were performed by single surgeon. All patients were followed clinically and radiographically for a minimum of 8 yrs. Mean 7.8 years and range from 7 to 9 years. The underlying diagnosis for majority of the cases were degenerative arthritis in 97 of the cases and rheumatoid arthritis on the 3%.

Result:

We have revised 6 cases - 3 cases were for sepsis .Theywere revised in 2 stages. And we also revised 5 cases for loosening of femoral component. The tibial component revision for aseptic loosening or osteolysis for an end point for survivorship was a 100% for the tibia monoblock design. There was no radiographic evidence of tibial component loosening or subsidence, or migration at the time of the latest follow-up for tibia monoblock. On the femoral part we documented 16 cases other than those 4 revision for osteolysis, where limited osteolysis happened in some area of the tibial component but it did not affect stability and those has been followed up for a longer term. There was interesting phenomena in some of those cases where bone growth happened around the anterior cortex where it sealed the component entirely. Knee society scores improved from 51 pre-operatively to 94 pre-operatively on the last clinical visit. We had 32 cases where the patientswere able to regain their full mobility flexion of over 150 degrees.

Conclusion:

Our data clearly shows that the cementless TKR has excellent result as compared to the cemented with a good survival ship at 10 years. The tantalum tibial component shows an excellent survivorship. The femoral component also present reasonably good result but we still faced a few cases of loosening. The functional outcome for the implant with the surgery was satisfactory. With this result we strongly recommend using the cementless implant in young patients. We believe that cementless tibial is totally safe at this point as well as the femoral cementless prosthesis .However, we expect some improvement with the outcome with the femoral component when using the tantalum.

#5528

Early Results of the Attune Knee System: A Minimum 2 Year Follow Up Observational Study

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Abstract

Introduction

Despite improvement in implants and surgical techniques up to 20% of Total Knee Arthroplasty TKA patients continue to report dissatisfaction. The ATTUNE Knee System was designed to provide better patellar tracking and stability through the mid-range of flexion and therefore improve patient outcomes and satisfaction.

Aims

The aims of this study were to assess patient outcomes in a consecutive series of ATTUNE TKA and ensure early results were comparable to other TKA systems in

Australia.

Methods

Between September 2014 and December 2015, 332 ATTUNE TKR's were implanted locally. All patients in our learning curve from case 1 were included. Mean follow-up was 2.6 years (range: 2.0-3.2). Revision, complications and postoperative ROM was collected. Patient reported outcome was measured using the Multi-Attribute Arthritis Prioritization Tool (MAPT) questionnaire. Revision rates were cross checked with an AOANJRR Ad Hoc report.

Results

Revision rate of the ATTUNE TKR was lower than national rates, however not statistically different (1.6% vs. 2.1%) ($p=0.508$). Postoperative MAPT scores were significantly lower after TKR (median 63.4 vs. 0.0) ($p<0.001$). A total of 86.7% patients had a good outcome postoperative TKR (MAPT$\leq$ 20).

Conclusion

Our findings suggest the ATTUNE TKR has comparable revision rates to other TKRs currently available in Australia. Furthermore, patient reported outcome was high 2.8 years postoperatively, with 85% patient satisfaction.

Keywords

Total Knee Arthroscopy; Patient Outcome; ROM (Range of Motion); ATTUNE; Osteoarthritis; Revision Rates

Cruciate Retaining Implant Has Superior Outcomes Over Posterior Stabilized Implant in Obese Patient and It Is a Better Choice to Reduce Early Post-Operative Complications

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Introduction:

Early complication post total knee replacement reported to be higher in obese patient in general. Also the outcome of cruciate retaining and PS knee has been fully discussed before and there was no major difference in the outcomes for all the patients overall regardless of their weight. However, the purpose of this paper is to find out if the CR knee has superiority over PS knee in terms of clinical and functional outcomes and if early complication postTKR such as fracture and instability is more common in PS implant than in CR knee. This is a retrospective study comparing two groups of obese patients. The first using PS implant and the other using CR implant. These two groups were matched for age, body mass and severity of deformity.

Materials&Methods:

At our institution we have been using Persona implant which has the option of using PS insert or a CR. The decision to proceed with CR or PS mainly depends on the availability of the implant and also the ability to well balance the knee in patients. In most patients we try to proceed with CR implant. However, the flow of implant sometime sometimes limit us from using CR or the imbalance in the ligament force us to process with PS implant.

We have reviewed a chart of over 200 patients in each group of obese patient they were done within the last three years. All cases had a minimum follow up of 6 months. Those groups were matched for body mass, age and severity of deformity. After matching the groups we documented Knee Society Score (KSS),Knee Society Function Score (KSFS) ,blood loss, post – operative pain and complications. All surgeries were performed by the same surgeon.

Results:

Our study showed that the clinical scores (KSS) in both groups were very close while significant differences were observed in functional scores (KSFS) for the CR knee .

We had 8 cases of per-prosthetic fracture in the PS group and one in the CR implant.

We had 4 revisions in the PS group for instability and MCL insufficiency and non in the CR implant.

Infection, wound complication, blood loss, and patient satisfaction were same in both groups.

Discussion:

This study suggests a significant difference in functional outcomes, especially walking, stair climbing and the use of walking aids, between CR and PS that favors CR implant which may be related to the CR knee retaining proprioception and ligaments tension with balance. In addition, PS knee have more varus-valgus and mid-flexion laxity than CR knee throughout the range of motion which appear clearly in obese patient .

On the other hand, the study clearly shows that the decrease incidence of peri-prosthetic fracture in the CR implant which could be easily explained by the fact that a good cortical bone is resected in order to make room for the PS spine. Also, the fact that resecting the posterior cruciate ligament might cause more stress on the implant versus the CR. Instability also were more common in the PS group. We believe this has to do with the fact that the PCL serve as a secondary constraint to the MCL. The presence of the PCL help maintain the stability in case of incidental injury to the MCL during surgery which was reported to be higher in obese patients.

Conclusion:

There is clear advantage of improving the outcomes or knee scores and decreasing the early postoperative complications in obese patient using CR knee and we strongly recommend using CR implant in obese patients in order to restore functionality faster and reduce the incidence of peri-prosthetic fracture and the revision for instability.

#6118

Short Term Clinical Results of Total Knee Arthroplasty With JourneyII BCS

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Background: Total knee arthroplasty (TKA) was primarily considered a successful procedure, several new knee implants were introduced in recent years that seek to obtain improved stability and higher flexion. One of the implant ,JourneyII^{TM} Bi-Cruciate Stabilized(BCS) , Smith & Nephew, TN, USA) recreates a specific kinematic model through the principle of guided motion

Patients and Method: An unselected consecutive series of seventyseven patients undergoing primary TKA using the cemented total knee system between August 2015 and April 2017 were studied. Thirty knees was operated using JourneyII BCS ,subsequently forty-one knees were received a TKA using cruciate retaining cemented total knee system FINE^{TM}CR. Postoperatively standing AP hip-to-ankle radiographs were obtained, from which the lower extremity mechanical axis, component angle were measured. The alignment goals were a neutral mechanical axis defined as a hip-to-ankle angle of 0°with the femoral and tibial components aligned perpendicular to the mechanical axis. The total operating time were quantified utilising an operating room database. The total operating time between TKAs performed with JourneyII BCS and those performed with FINE was compared in each group. All patients postoperatively was evaluated of clinical results the Japan Orthopedics Association(JOA) Knee scores. We evaluated femoral component posterior offset(PFCO) in both of two group . The maximal protrusion of the posterior condyle, posteriorly to the extension line parallel to the tibial shaft from the edge of the posterior tibial component was measured on true lateral radiographs.

Results: The JOA Knee score of Journey II group was 83.3±6.3 points, and the score of FINE group was 82.7±5.9 points, there was no statistical significance between the two groups on the clinical score. The operative time in Journey II was 127.0±14.6 minutes and significantly more compared to the time of FINE group minutes. The mechanical axis angle in JourneyII BCS group was -0.9°±3.2, while FINE group was -0.7°±3.2, there was no statistical significance. The number of outliers for mechanical axis angle was JourneyII BCS group 25%, the FINE group 24%, between the two groups there was no statistical significance.The mean value of the posterior offset ratio of JourneyII BCS was 8.5%±0.1. The mean value of the posterior offset ratio of FINE group was 16.7%±0.1 , between the two groups there was statistical significance.

Discussion: Bellemans et al. first defined th concept of posterior condylar offset. They demonstrated that the maximum active flexion possible was limited by direct impingement of the posterior aspect of the tibial component against the posterior aspect of the femur. However, the offset also reduces the extension gap. An enlarged posterior femoral component may reduce the extension gap due to posterior tissue tightness. In this study, the posterior offset of JourneyII BCSwas good results compared to the CR type FINE. Clinical results and the mechanical axis angle was good both of the group, but the operative time in Journey II was significantly more compared to the time of FINE group.

Conclusion: Good early clinical results were obtained with JourneyII BCS knee implant, long-term follow-up studies are needed to confirm our findings.

Two Cases Reports of Total Knee Arthroplasty (TKA) With Schizophrenia

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Background

Kohnodai Hospital merged with the National Center of neurology and Psychiatry in Japan in 1987. Accordingly, we treat more patients with mental disorders than other hospitals. I treated two patients with schizophrenia for TKA.

Case 1

A 44 year-old female with schizophrenia and malignant rheumatoid arthritis presented with bilateral knee pain and difficulty walking. Her range of motion (ROM) was: right knee; extension -95°, flexion 120°, left knee; extension -95°, flexion 120°. Her Knee Society Bilateral Score was 19 points, X-ray grade: Larsen 5, Steinbrocker grade: Stage 3, class 4. Pre-TKA, corrective casts improved her ROM (extension; right -75°, left -70°). She received right TKA in September, 2013, and left TKA in December 2015. Post-operation bilateral ROM: extension -15° and flexion 120°. After operation, she wore corrective casts. Post TKA, she received manipulation for bilateral knee contractions in 2015, and she began in-patient rehabilitation. Her progress was normal, and became able to stand easily with a walker. However, after discharge, she discontinued treatment for schizophrenia and refused outpatient rehabilitation, possibly due to her schizophrenia. Thereafter, she lost her ability to stand up easily. Her ROM worsened, right: extension -95°, flexion 115°, left: extension -75°, flexion 115° JOA score; Bilateral 30 points.

Case 2

A 69 year-old male with schizophrenia presented with right knee pain and received hyaluronic acid injections in his knee. He had diabetes and reflux esophagitis at first visit. His ROM was: extension -10° flexion120°, and his Knee Society Score was 34 points. He received TKA in November 2015. He began to walk with full weight bearing the following day after, while continuing his treatment for schizophrenia. In 2018, his ROM was: extension -15° and flexion 105°. JOA Score was 85 points, and he could ascend stairs normally. After discharge, he had continued rehabilitation together with satisfactory control of his schizophrenia, and his normal prognosis was achieved.

Discussion

Schizophrenia affects about only about 1% of the population, and TKA with schizophrenia is rare. Refusing rehabilitation due to schizophrenia may adversely influence prognosis. Proper control of schizophrenia may be important to avoid patients' refusing rehabilitation.

Conclusion

Refusing rehabilitation due to schizophrenia may adversely influence prognosis in schizophrenia patients receiving TKA, and working in tandem with a psychiatrist should be considered for such patients.

#5626

Correlation Between the Tibiofemoral Anteroposterior Position in Knee Mid-Flexion Range and Clinical Results in Journey BCS-TKA

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Background: Journey II BCS-TKA is a model designed to guide normal kinematics by the anatomical component designand the post-cam mechanism compensating for the anterior and posterior cruciate ligament function. On the other hand, actual knee kinematics after these guided motion TKA and the effects for the clinical results are still unclear. In this study, we analyzed the anterior-posterior (AP) position between the femur and tibia at mid-flexion rangebefore and after TKA and evaluated those effects on clinical outcome.

Materials and methods: For the 41 knees who performed TKA using Journey â…¡BCS (Smith & Nephew) by the measured resection method, the positions of the femur to the tibia were calculated from the values measured by Precision Knee Navigation system 4.0(Stryker) at a flexion angle of 45 degrees before and after TKA. Furthermore, the changes amount of the AP position before and after TKA was calculated, and the correlations with the range of motion (ROM) and the Knee Society Score (KSS) were evaluated using the Spearman rank correlation coefficient (ρ). The significance level P <0.05 was set.

Results: The postoperative range of motion improved significantly. The extension angle improved from 10.1 degrees to 1.0 degree, and the flexion angle improved from 123.8 degrees to 129.8 degree. The changes of AP position which is defined by the change amount of the postoperative position from the preoperative one had significant correlations with postoperative flexion range and KSS Patient Satisfaction ($\rho = 0.46$, $p = 0.01$, $\rho = 0.5$, $p = 0.01$, respectively). On the other hand, there was no correlation between the changes of AP position and, extension range of motion, preoperative AP position and clinical outcome. Moreover, posterior sloopangle of tibial implant had no correlation with changes of AP position, postoperative ROM and postoperative clinical outcomes.

Discussion: From the results of this study, in cases which AP position in the mid-flexion rangehad less change before and after the surgery, the KSS patient satisfaction showed a higher value and more range of motion was acquired. This is considered to reproduce normal knee kinematicscase in which after TKAthe femur translates from anterior position to the tibia at the extension position toward the posterior position at the mid-flexion position,like the so-called roll back motion. On the other hand, in cases which the AP position of the femur to the tibia was located in anterior positonin the mid-flexion range after TKA showed lower KSS patient satisfaction score and less flexion range of motion.

Journey II BCS was designed to guide the position of the femur relative anterior to the tibia in the extension position. However, it indicated that if the Roll back motion was not reproducedat the mid-flexion position, it would affect the postoperative clinical outcome. In a future work, it is necessary to analyze more cases and we try topropose operative techniques to reproduce normal knee AP kinematics efficiently.

Figures

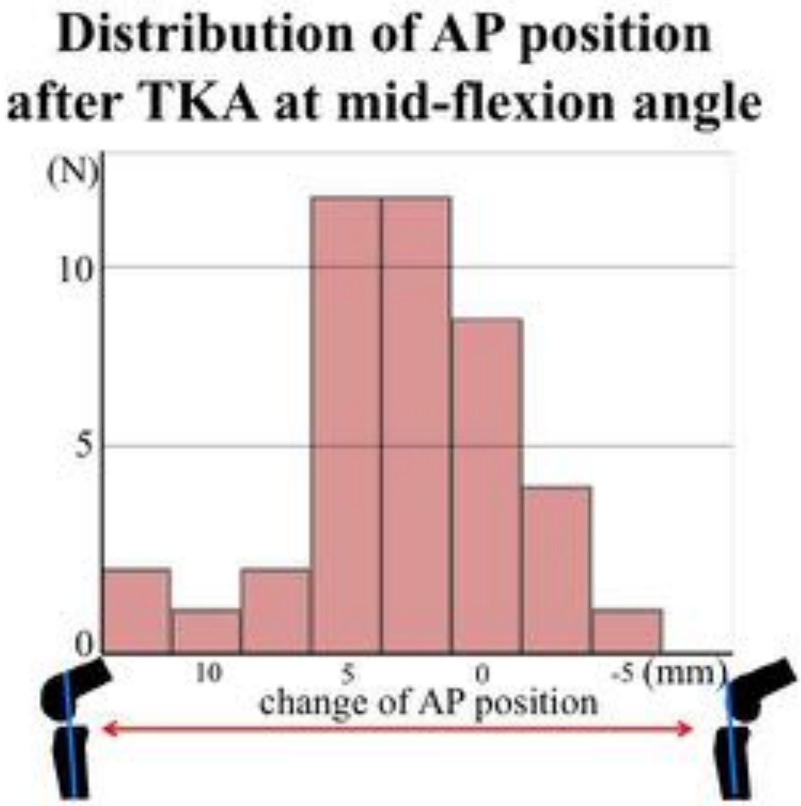

Figure 1

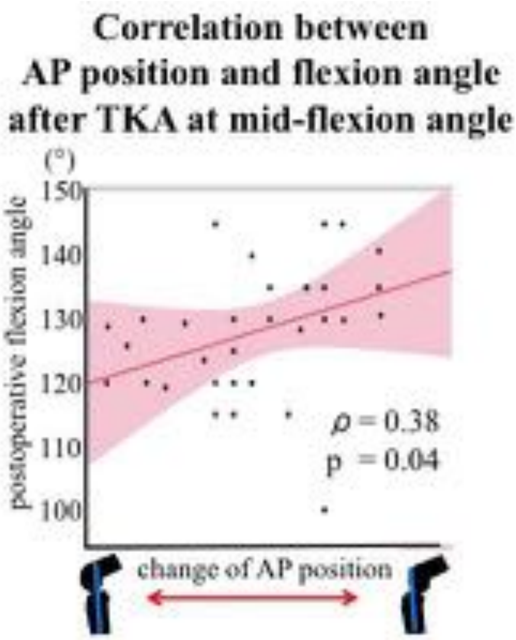

Figure 2

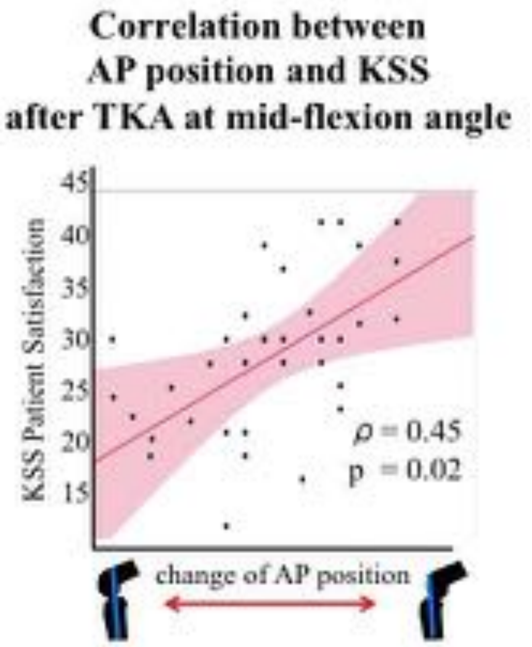
Correlation between
AP position and KSS
after TKA at mid-flexion angle
KSS Patient Satisfaction
45
40
35
30
25
20
15
ρ = 0.45
p = 0.02
change of AP position

Figure 3

#6190

Mid-Term Outcomes and Complications of Total Knee Arthroplasty: A Review of 404 Knees in a Single Institute, FINE Knee (CR).

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Introduction

Obtaining good stability and range of motion is the most important aspect for restoring excellent function of the knee joint after total knee arthroplasty (TKA).

Objective

ã€€We report on the knee joint Range of Motion (ROM) and the JOA Score for the 404 knees which performed surgery using our surface replacement surgery method and FINE knee (CR). Additionally, we analyzed the poorly ROM knee of 100 degrees or less before the operation and the regular knee after the operation.

Subjects

FINE knee (CR) who underwent operation at our hospital for about three years from January 2012 to December 2015, excluding the Valgus knee and the Revision total knee arthoplasty. 404 knees. OA:401 knees, RA:3 knees. The average age was 73.6 years old. The cases with less than 100 degrees before the operation were 20 knees, 5%.

Results

Range of motion and the JOA score before and after surgery. The average pre-operative range of motion of the 404 knee is -5.1 degrees to 132.2 degrees. The mean range of motion after surgery was improved, from -1.3 degrees to 135.4 degrees. The knee flexion angle was measured by holding the knee. The JOA score improved from 64.1 points to 78.2 points at 4 weeks post-operatively. ROM knee of 100 degrees or less before the operation group average maximum flexion angle improved to 122.0 degrees (± 9.5). In this period, infection was one case, the replacement of the tibial implant by loosening was one case.

Conclusion

We reported the FINE knee (CR) ROM of 404 knees. The mean maximum flexion angle after operation was 135.4 degrees (± 12.9).

#5602

Body Mass Index Does Not Impact the 13 Year Survival After Mobile Bearing Total Knee Arthroplasty

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INTRODUCTION

Total knee arthroplasty (TKA) is considered a highly successful procedure. Survival rates of more than 90% after 10 years are generally reported after implantation of conventional, fixed bearing TKAs. However, complications and revisions may still occur for many reasons, and some of them may be related to polyethylene wear. It has been suggested that patients with higher body mass index (BMI) may experience more long term failures due to overload of the polyethylene component. The use of a mobile bearing has been suggested to decrease polyethylene wear and improve long term survival. However, clinical relevance of this design change remains debated. The present study was designed to evaluate the long-term (more than 10 years) results of mobile bearings TKAs on a national scale, and to assess the impact of the initial BMI on the long term survivorship.

The primary hypothesis of this study will be that the 15 year survival rate of obese patients will be decreased in comparison to that of non obese patients after implantation of a mobile bearing TKA..

METHODS

All patients operated on between 2001 and 2004 in all participating centers for implantation of a TKA (whatever design used) were eligible for this study. Usual demographic and peri-operative items have been recorded, and especially the index BMI. All patients were contacted after the 10 year follow-up for repeat clinical and radiological examination (KSS, Oxford knee questionnaire and knee plain X-rays). Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information about prosthesis survival. Survival curve was plotted according to the actuarial technique, using the revision for mechanical reason as end-point. The influence of the index BMI was assessed with a logrank test at a 0.05 level of significance.

RESULTS

1,604 TKAs were implanted during the study time-frame. 603 patients (37%) were considered obese (BMI>30 kg/m²). There was no difference in any other baseline criteria between obese and non obese patients. 289 patients deceased before the 10 year follow up (18%). Final follow-up was obtained for 926 cases (58%). 18 prosthetic revisions were performed for mechanical reasons during the follow-up time (1%). The global survival rate after 15 years was 97%. There was no significant difference between the 13 year survival rates of obese (98%) and non obese (97%) patients.

DISCUSSION

The primary hypothesis of this study was not confirmed: no difference was observed between obese and non obese patients when considering the 13 year survival rate for mechanical revision after mobile bearing TKA. Mobile bearing TKA allows using a more conforming polyethylene piece, which may decrease polyethylene wear, especially by obese patients. Obesity should not be a contra-indication for mobile bearing TKA, and obese patients should not be considered as high risk patients for mechanical revision after implantation of a mobile bearing TKA.

Long-Term Results of Total Knee Arthroplasty With Single-Radius Versus Multi-Radius Posterior-Stabilized Prosthesis in Rheumatoid Arthritis

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Object: Although single-radius designs have theoretical advantages in some aspects, there has been a paucity of evaluation studies. The purpose of this study was to compare 10-year clinical, radiological, survivorship outcomes of single radius and multi radius posterior stabilized prosthesis in total knee arthroplasty(TKA) with Rheumatoid Arthritis (RA).

Method: In this retrospective observational study, we reviewed 240 patients (240 knees) with RA who underwent TKA between Oct 2005 and Dec 2007: SR group (120 patients, 120 knees, Stryker Scorpio NRG) and MR group (120 patients, 120 knees, Depuy sigma RP). A 1 âˆ¶ 1 matched case control study was conducted in two groups which were similar in terms of age, gender, BMI, ASA classification and operation team. Mean follow-up periods were 10.73±1.13 (range: 8–13) years and 10.82±1.09 (range: 7–13) years.

Results: In SR group, the mean HSS score improved significantly from 38.63±8.76 to 87.67±6.62, the mean VAS score decreased significantly from 7.37±0.24 to 0.45±0.12. the mean range of motion improved significantly from 105.52°±7.78°to 124.32°±8.12° (p<0.001). In MR group, the mean HSS score improved significantly from 38.75±8.34 to 89.29±5.21, the mean VAS score decreased significantly from 7.62±0.26 to 0.33±0.10. the mean range of motion improved significantly from 104.18°±7.62° to 122.52°±8.03°(p<0.001). (See Figure 1) Clinical and functional improvements had no significant differences between the two groups. 6 complications were noted in SR group, including 2 cases of prosthetic loosening, 1 case of periprosthetic osteolysis, 3 cases of periprosthetic bright lines.6 complications were noted in MR group, including 2 cases of prosthetic loosening and 4 cases of periprosthetic bright lines. No case of infection was observed in two groups. Survivorship using Kaplan-Meier survival analysis was 97.5% (95% confidence interval [CI]: 96.8–98.3%) for the SR at 10 years and 98.3% (95% CI: 97.3–99.5%) for the MR group at 10 years, with no significant difference (p=0.755). (See Figure 2)

Conclusion: This study suggested that both single-radius and multi-radius posterior stabilized prostheses can lead to satisfactory outcomes for clinical function, radiological evaluation and survivorship among RA patients undergoing TKA, and no significantly clinical differences was shown in two types of prostheses.

Figures

Figure 2 Clinical Results

	SR Group	MR Group	P value between group
HSS			
Preoperative	38.63±8.76	38.75±8.34	0.978
Last Follow	87.67±6.62	89.29±5.21	0.221
P value in group	0.001	0.001	-
HSS improvement	49.04±10.5	50.54±9.4	0.983
VAS			
Preoperative	7.37±0.24	7.62±0.26	0.407
Last Follow	0.45±0.12	0.33±0.10	0.447
P value in group	0.001	0.001	-
VAS decrease	6.92±1.01	7.29±1.23	0.252
ROM			
Preoperative	105.52°±7.78°	104.18°±7.62°	0.963
Last Follow	124.32°±8.12°	122.52°±8.03°	0.678
P value in group	0.001	0.001	

Figure 1

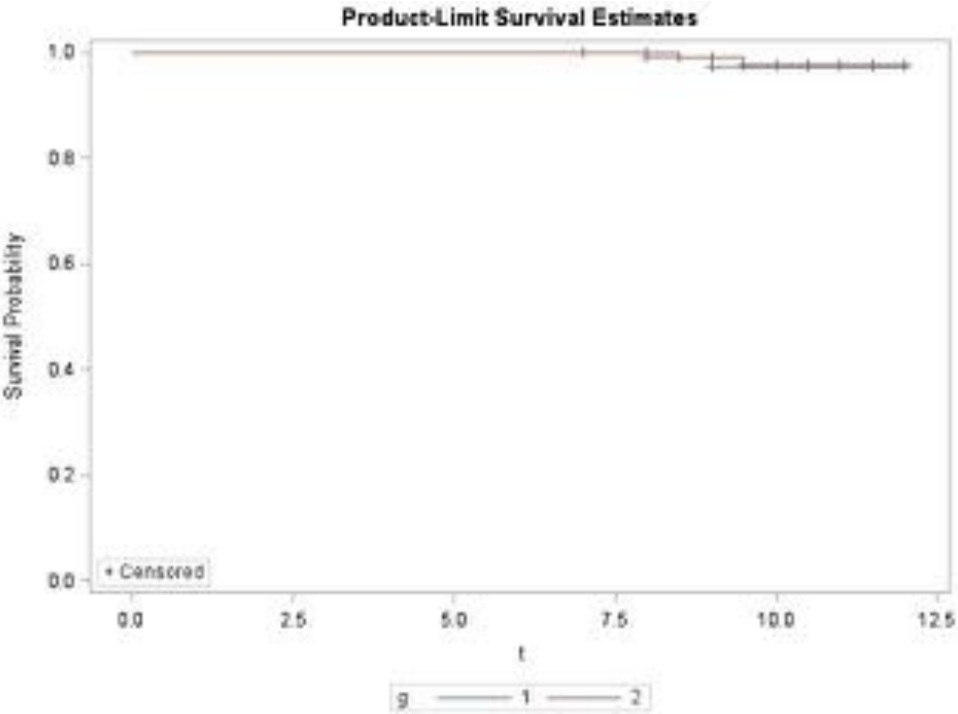

Figure 2

Medial Tibial Periprosthetic Bone Resorption and Its Effect on Clinical Outcomes After Total Knee Arthroplasty: Cobalt-Chromium Versus Titanium Implants

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Recently, concerns arose over the medial tibial bone resorption of a novel cobalt-chromium (CoCr) implant. This study aimed to investigate the effects of tibial component material, design, and patient factors on periprosthetic bone resorption and to determine its association with clinical outcomes after total knee arthroplasty (TKA). A total of 462 primary TKAs using five types of implants were included. To evaluate tibial periprosthetic bone resorption, we assessed radiolucent lines (RLL) and change in bone mineral density at the medial tibial condyle (BMDMT). Factors related to bone resorption were assessed using regression analysis. Clinical outcomes were also evaluated with respect to periprosthetic bone resorption. Compared to titanium (Ti) implants, CoCr implants showed a higher incidence of complete RLL (23.1% vs. 7.9% at two years post-TKA) and a greater degree of BMDMT reduction. However, there was no significant difference between the implants made of the same material. Increased medial tibial bone resorption was associated with male sex, osteoporosis, larger preoperative varus deformity, longer follow-up period, and lower body mass index. The periprosthetic bone resorption was not associated with clinical outcomes including changes in range of motion and WOMAC score. Furthermore, no cases warranted additional surgery. Periprosthetic bone resorption was associated with implant material but not with implant design. Moreover, patient factors were related to the medial tibial bone resorption post-TKA. However, the periprosthetic bone resorption was not associated with short-term clinical outcomes. We contend that researchers should incorporate integrative considerations when developing and assessing novel implants.

Figures

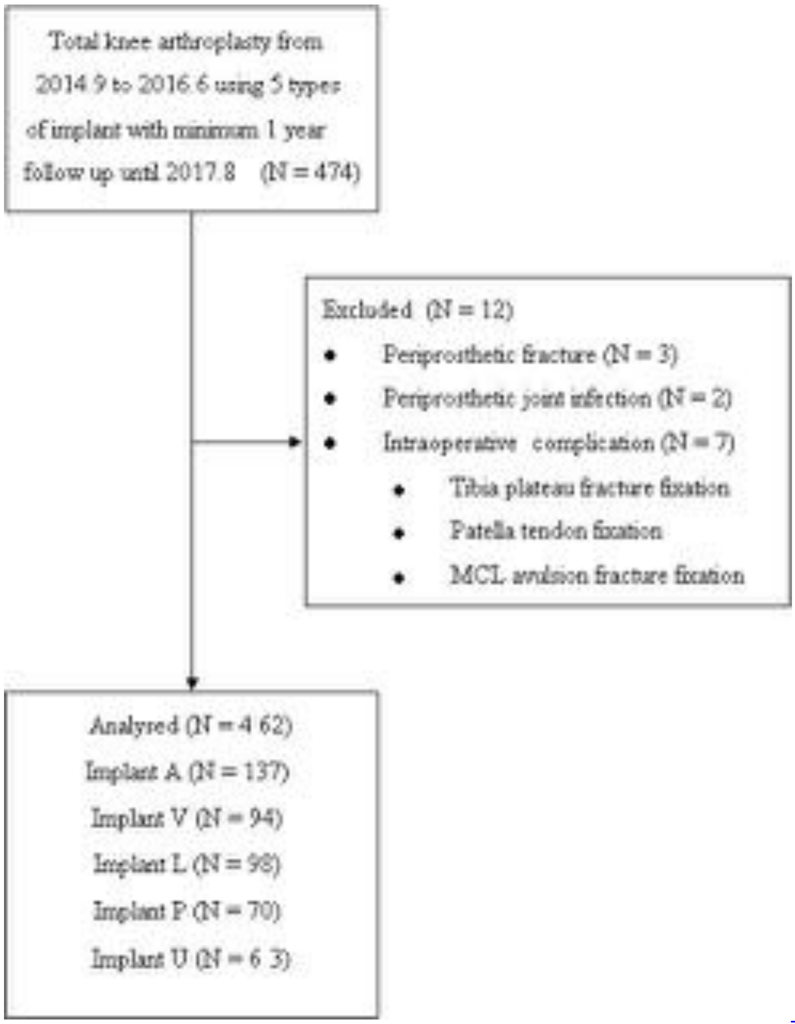
Total knee arthroplasty from 2014.9 to 2016.6 using 5 types of implant with minimum 1 year follow up until 2017.8 (N = 474)
Excluded (N = 12)
Periprosthetic fracture (N = 3)
Periprosthetic joint infection (N = 2)
Intraoperative complication (N = 7)
Tibia plateau fracture fixation
Patella tendon fixation
MCL avulsion fracture fixation
Analyzed (N = 4 62)
Implant A (N = 137)
Implant V (N = 94)
Implant L (N = 98)
Implant P (N = 70)
Implant U (N = 6 3)

Figure 1

Figure 2

Figure 3

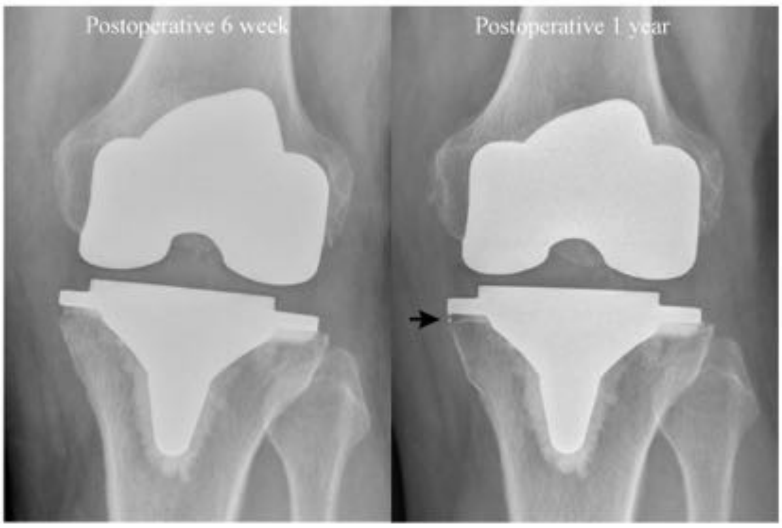

Figure 4

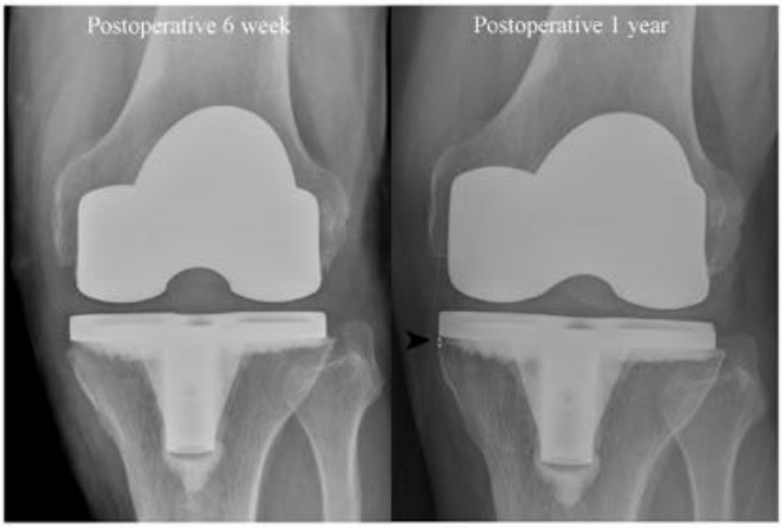

Figure 5

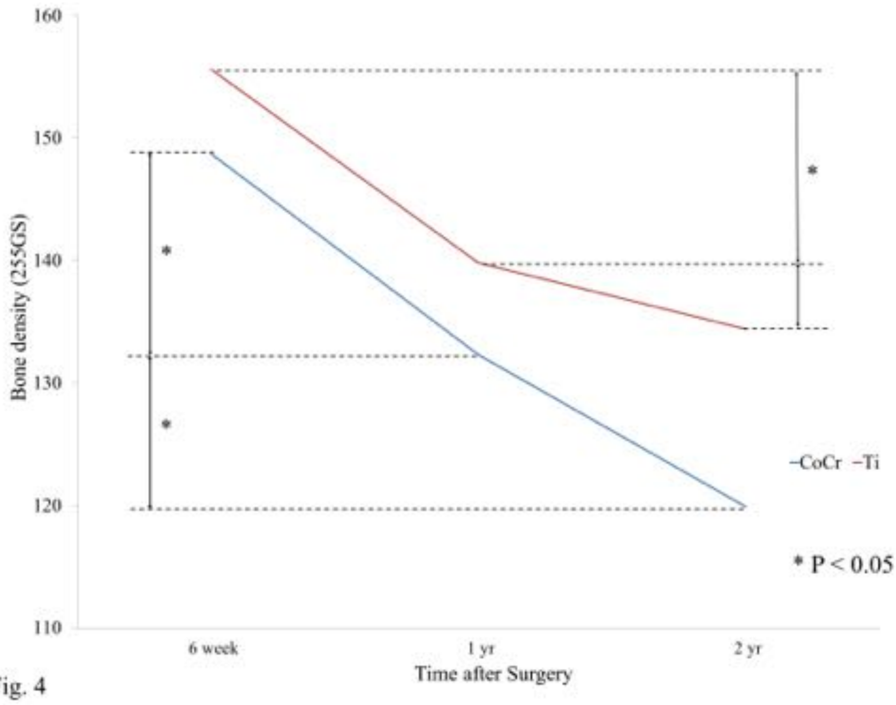

Fig. 4

Figure 6

#5964

Test Method to Investigate Secondary Lockdown Bolt Loosening in Total Knee Arthroplasty

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Introduction: A search of the literature indicates several constrained total knee arthroplasty (TKA) systems are at risk for articular surface lockdown bolts backing out (1-3). The backing out of a lockdown bolt may lead to an unstable and/or painful knee and may necessitate revision. Upon backing out, the bolt may damage implant components and surrounding tissues. To date, studies in the literature have not simulated or replicated loosening of bolts in TKA. Therefore, the objectives of this study were to 1) develop a set of physiological loading parameters that challenge bolted articular surfaces, 2) evaluate whether significant bolt torque is lost during application of this loading to a CCK device with a bolt as a secondary locking mechanism.

Materials and Methods: Physical test parameters to loosen lockdown bolts were developed based on loading experienced during activities of daily living (see Figure 1). Sinusoidal waveforms and timing were used to simulate worst case walking gait conditions. Compared to data from everyday activities in instrumented TKR patients, anterior posterior loads and internal/external torques exceeding the absolute maximums observed were selected. To transfer more shear and torsion to the joint interface, compressive load lower than typically reported for walking gait was used. Frequency was representative of walking gait motion.

The offset in torsional waveform enables a ratcheting motion to drive a loose bolt out of the joint: during external femoral rotation of a left knee, reduced compressive load and posterior directed femoral loading on a CCK spine creates a potential articular surface lift-off. The lift-off may grab the underside of the front bolt shoulder while external (CCW) rotation loosens the bolt. These loading conditions exist during toe-off of walking gait (4).

Two CCK devices were evaluated to capture potential difference in performance: a medium articular surface combination and a smaller articular surface combination (Figure 2A, n=5 each). Testing was performed on a load frame capable of rotation and vertical / horizontal translation.

Results: No bolts completely loosened when fully tightened. However, average loss in bolt torque of 39.3% on the medium and 21.5% on the smaller articular surface was observed. Loading led to reorientation of the articular surfaces verified by markings on the components (Figure 2B). Additional constructs that were under-tightened intentionally to one-quarter of target torque value lost all bolt torque and completely backed out.

Discussion and Significance: The backing out of lockdown bolts in TKA has been reported in the literature but not replicated in-vitro. A challenging, physiologically relevant set of loading parameters was developed and applied to a CCK device with an articular surface lockdown bolt. Upon loading, the bolts experienced statistically significant loss of bolt torque which may be attributed to articular surface reorientation. Selected loading parameters led to complete bolt back-out in under-tightened constructs.

References:

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Figures

Loading	Compressive (N)	-1700 N to -170 N
	A/P (N)	300 N to – 300 N
	Torsional (N*m)	20 N*m to – 20 N*m (80° phase lag)
	Frequency	1 Hz
Bolt tightening		95 in*lb
Sample size		5
Test duration		1000 cycles
Test medium		Air

Figure 1

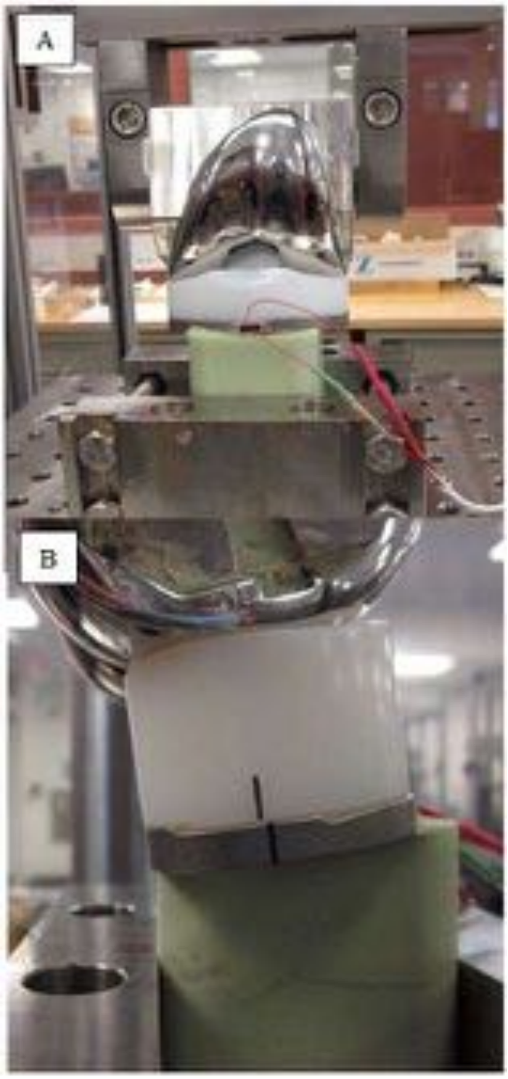

Figure 2

#5918

Internal Mal-Rotation of the Tibial Component Is a Cause of Flexion Contracture After TKR : In-Vivo Study

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Introduction:Stiffness postTotal Knee Replacement (TKR) is a common,complex and multifactorial problem. Many reports claim that component mal-rotation plays an important role in this problem. Internal mal-rotation of the tibial component is underestimated among surgeons when compared to femoral internal mal-rotation. We believe the internal mal-rotation of thetibial component can negatively affect the full extension of Knee. We performed an in-vivo study of the impact of tibial internal mal-rotation on knee extension in 31 cases.

Method: During TKR, once all bony cuts were completed and flexion/extension gaps balanced, we assessed the degree of knee extension using the trial component in the setting of normaltibial rotation and with varying degrees of internal rotation (13-33â°, mean 21.2±4.6â°). Intra-operative lateral knee X-ray was done to measure the degree of flexion contracture in both groups. We also compared the degree of flexion contracture between CR and PS spacers.

Results: The average degree of knee flexion contracture with normal rotation of the tibial component was 0.7±4.1â° (range:-9 to 10), whereas after tibial internal rotation was 7.3±4.6â° (range:-1 to 23)(P – value:0.001). The increase in the flexion contracture deformity was higher with PS spacer (7.18±2.61) than with CR spacers (5.22±2.05)

Conclusion: The internal mal-rotation of the tibial component limits the ability of the tibia to externally rotate on the femur, thereby limiting full knee extension and leading to flexion contracture.

#5830

Anterior Knee Pain After Total Knee Arthoplasty

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Purpose: Anterior knee pain after total knee arthroplasty (TKA) reduces patients' satisfaction and quality of life. Various causes of anterior knee pain after TKA have been reported in the literature; inadequate operative technique, instability, malrotation of component, lesion caused by extension mechanism, inadequate biomechanics of the lower limb, patellofemoral joint lesion and malalignment, firm soft tissue, weakened muscle, with or without patellar resurfacing, and design of the implant. We experienced cases of tightness of quadriceps muscle associated with anterior knee pain after TKA. In this study, we evaluated if the tightness of quadriceps muscle is one of the causes of anterior knee pain after TKA.

Materials and methods: One-hundred sixty-two patients (244 knees) who underwent TKA by one surgeon with modified gap technique using the Nexgen® Legacy Posterior-Stabilized (LPS) implant with a minimum 1-year follow-up were included in the study; patellar resurfacing was not performed. The experimental group (Group 1) included 28 patients (44 cases; mean age 71) who complained of anterior knee pain (anterior knee pain upon daily life activities, such as prolonged sitting, climbing up or down the stairs). The control group (Group 2) included 134 patients (200 cases; mean age 70). Clinical evaluations included body mass index (BMI), range of motion, presence of swelling and quadriceps atrophy, and the tightness of quadriceps muscle which was evaluated using Q-flexibility angle. Radiological analysis included patellar height (Insall-Salvati ratio), lateral patellar tilt, and mechanical axis of the lower limb.

Results: The body mass index (BMI) was 22.7 in Group 1, and 22.4 in Group 2. Mean flexion contracture was 2.0^{o} and further flexion 127.8^{o} in Group 1, 0.6^{o} and 131.7^{o} in Group 2, respectively ($p=0.16$). Presence of swelling and quadriceps atrophy were 43%, 68% in Group 1, and 23%, 42% in Group 2, respectively ($p<0.05$). When the Odds Ratio (OR) of developing anterior knee pain was calculated, it was found that the incidence of anterior knee pain after TKA was 2.54 and 2.89 higher in patients with continuous swelling and quadriceps atrophy was present. The Q-flexibility angle was significantly higher in Group 1 15.5^{o} than in Group 2 10.4^{o} ($p<0.05$). Significant tightness of quadriceps muscle was defined as having Q-flexibility angle of 20 degrees or more. The OR was calculated to be 4.52 times higher with significant tightness of quadriceps muscle.

According to measured Patellar height (Insall-Salvati ratio) was 1.09 in Group 1, and 1.17 in Group 2 ($p=0.26$). Lateral patellar tilt was 2.80^{o} in Group 1, and 2.53^{o} in Group 2 ($p=0.50$). The mechanical axis of the lower limb was varus 0.54^{o} in Group 1, and varus 0.99^{o} in group 2 ($p=0.24$). The patellar height and tilt, and the mechanical axis of the lower limb did not differ significantly between the two groups.

Conclusion: Anterior knee pain after TKA may have several causative factors. In this study, when the comparison between the two groups and the OR was considered, tightness of quadriceps muscle was one of the important cause of anterior knee pain after TKA.

Key words: total knee arthroplasty (TKA), anterior knee pain, tightness of quadriceps muscle.

#6004

A Holistic Approach to Optimize the Pain Management Strategy After Tka: A Prospective Observational Report

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Introduction:

Pain management for TKA not only aims for optimal patient comfort in the immediate perioperative period, but also is imperative for permitting an optimal recovery and rehabilitation process. It’s difficult to design a standard protocol that works for each individual patient given the influence of a multitude of psychological factors, genetic differences, previous analgesic consumption and surgical complexity. In addition to an optimized surgical approach and multimodal analgesic strategy, fast adjustments of the pain-killing and anti-inflammatory therapy in the first postoperative weeks by virtue of 24/7 follow-up is beneficial for an optimized pain treatment. Such optimized pain management is also believed to decrease the consumption of opioids and decrease the risk of evolution to persistent post-surgical pain.

Materials and methods:

For postoperative management optimisation, a new postoperative cloud-controlled Recotech® tool (moveUP, Class 1, CE-certified, medical device) was used. This tool provides interactive and remote monitoring of activity, pain scores and the rehabilitation progress, and permits therapeutic intervention or direct patient communication if required. It also provides accurate recording of the evolution of the variables of interest, and the occurrence of complications, for research purposes.

The aim of this study was to evaluate the quality of the pain-killing strategy, quantified by patient-reported pain and comfort scores in the immediate postoperative period until 3 months after surgery. We hypothesize that our optimized and continuously adjusted pain management will result in a decreased consumption of opioids and decreased incidence of persistent post-surgical pain.To evaluate the pain and concomitant pain medication we used the WHO pain ladder.

Results:

In our cohort of 71 TKA patients, 14% are in the mild pain level (level 1), 4% are in the moderate pain level (level 2) and no patients were found to be in level 3 (severe pain) at 3 months after surgery. Strong opioid medication was stopped on average at day 4 postop, mild opioid medication was stopped on average at day 14 postop and the use of level 1 pain medication and anti-inflammatory medication could be stopped on average at day 34 postop. There were no reports of persistent post-surgical pain as at three months the pain was under control for 100% of the patients. The 6 month results so far have shown no single unsatisfied patient, with an average KSS score of 34.6 on a scale of 40.

Discussion:

In literature some studies show up to 45% of patients taking painkillers after 3 months and 6-10% describe unsustainable pain that require even stronger painkillers resulting in unsatisfied patients after TKA between 15-30%.

Conclusion:

Optimizing the pain management requires a holistic approach of optimized surgical technique, anaesthesia management and an individualised rehabilitation path with continuous adjustments according to patient needs. Such a strategy seems to prevent the evolution to persistent post-surgical pain and clearly minimizes opioid use.

#5840

Concomitant Ankle Osteoarthritis Is Related to Increased Ankle Pain and a Worse Clinical Outcome Following Total Knee Arthroplasty

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Background: Occasionally, patients experience new or increased ankle pain following total knee arthroplasty (TKA). The aims of this study were to determine (1) how the correction of varus malalignment of the lower limb following TKA affected changes in alignment of the ankle and hindfoot, (2) the difference in changes in alignment of the ankle and hindfoot between patients with and without ankle osteoarthritis (OA), and (3) whether the rate of ankle pain and the clinical outcome following TKA differed between the 2 groups.

Methods: We retrospectively reviewed prospectively collected data of 56 patients (99 knees) treated with TKA. Among these cases, concomitant ankle OA was found in 24 ankles. Radiographic parameters of lower-limb, ankle, and hindfoot alignment were measured preoperatively and 2 years postoperatively. In addition, ankle pain and clinical outcome 2 years after TKA were compared between patients with and without ankle OA.

Results: The orientation of the ankle joint line relative to the ground improved from varus 9.4° to varus 3.4°, and the valgus compensation of the hindfoot for the varus tilt of the ankle joint showed a 2.2° decrease following TKA. Patients in the group with ankle OA showed decreased flexibility of the hindfoot resulting in less preoperative valgus compensation ($p = 0.022$) compared with the group without ankle OA. The postoperative hindfoot alignment was similar between the 2 groups because of the smaller amount of change in patients with ankle OA. The group with ankle OA had a higher rate of increased ankle pain (38% compared with 16%) as well as a worse Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score (mean of 22.2 compared with 14.2) following TKA.

Conclusions: A considerable proportion of patients who underwent TKA had concomitant ankle OA with reduced flexibility of the hindfoot. These patients experienced increased ankle pain following TKA and a worse clinical outcome.

#5492

Over 15 Years of Long Term Clinical Results of Cementless CR Type TKA; Hi-Tech Knee II in Patients With Rheumatoid Athritis

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Background: Total knee arthroplasty (TKA) is a common form of treatment to relieve pain and improve function in cases of rheumatoid arthritis (RA). Good clinical results of TKA in patients with RA have been reported using several types of prosthesis. The decisions regarding whether the posterior cruciate ligament (PCL) should be replaced or retained and whether the prosthesis should be fixed using cement or not are made at the surgeon's discretion. Long-term (≥â€…10 years) follow-up studies of cruciate-retaining (CR) TKA without cement fixation of the prosthesis in patients with RA have indicated prosthesis survival rates of over 90%. The cementless Hi-Tech Knee II CR-type prosthesis (Teijinn Nakashima co. Ltd. Tokyo, Japan), which has 6 fins at the anterior of the femoral component, posterior cruciate ligament (PCL) retention, flat-on-flat surface component geometry, all patellae were also fixed with all-polyethylene components without cement, strong initial fixation by the center screw of the tibial base plate, 10 layers of titanium alloy fiber mesh, and direct compression molded ultra high molecular weight polyethylene (UHMWPE).

Purpose: The present study was performed to evaluate over 15 years of long term clinical results of primary TKA in RA patients using the cementless Hi-Tech Knee II CR-type prosthesis.

Materials and Methods: We performed 153 consecutive primary TKAs using cementless Hi-Tech Knee II CR-type prosthesis in 142 RA patients. We can evaluate on 33 knees and 27 patients who have been followed over 15 years. The follow-up period was 15 years 3 months to 21 years 5 months (average 17 years 7 months). Clinical evaluations were performed according to the American Knee Society (KS) system, knee score, function score, radiographic evaluation, and complications.

Results: The mean postoperative maximum flexion angle was 116.2°, and the KS knee score and function score improved to 87 and 72 after surgery, respectively. Complications, there were one cases of late deep infection, but no cases of nerve palsy, pulmonary embolism, deep vein thrombosis, and patella fracture. There were no cases of loosening in this cohort, even of all-polyethylene patella and the prosthesis survival rate was 96.9% at over 15 years postoperatively.

Discussion and Conclusion: The disease state of the RA knee at the time of arthroplasty dictates whether the PCL is retained or sacrificed and whether cement is or is not used. Therefore, we did not use this prosthesis for all RA knees. The contraindications for use of this prosthesis include cases with mutilating type RA, severe deformity, severe knee stiffness, and severe instability of the knee. We did not consider metaphyseal tibial defect as a contraindication for use of this prosthesis.

These results suggest that TKA using the cementless Hi-Tech Knee II CR-type prosthesis is a very effective form of treatment in RA patients even over 15 years postoperatively. Further long-term follow-up studies are required to determine the ultimate utility of this type of prosthesis.

#6129

Association Between Tibial Coronal Alignment in Posterior-Stabilized Primary Total Knee Arthroplasty and Patient Satisfaction: Using a 3D-Matching Evaluation Method

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Purpose: The aim of the present study was to evaluate tibial coronal alignment of posterior-stabilized primary total knee arthroplasty (TKA) using 3D-reconstructed computed tomography (CT) scans and assess the relationship between tibial coronal alignment and clinical outcome.

Methods: A total of 33 consecutive patients who underwent primary TKA were included in the present study. Preoperative diagnoses were osteoarthritis in all knees. VANGUARD (Zimmer-Biomet) components were used in 26 knees and ATTUNE (DePuy Synthes) were used in 7 knees. TKAs were performed at our institution between July 2014 and January 2017. For the assessment of TKA component positioning, we used a 3D matching evaluation method. In this method, preoperative planning was accomplished using 3D templates. We also performed CT scans of the lower limbs both pre- and postoperatively. The tibial component setting was located and evaluated after surgery using evaluation software made in LEXI Company. For clinical outcome scoring, the Japanese Knee Osteoarthritis Measure (JKOM) was used at 6-months and 1- and 2-years postoperatively. Patients were asked to grade their level of satisfaction for each question (i.e. 'very dissatisfied', 'dissatisfied', 'neutral', 'satisfied' or 'very satisfied'). The patients were divided into two groups: a neutral alignment group (n = 26; preoperative alignment ± 2°), and an outlier group (n = 7; preoperative alignment > 2°). We compared these two groups for JKOM and level of satisfaction. And we investigated the correlations between tibial coronal alignment and JKOM.

Results: There was a significant difference in the number of patients who answered 'satisfied' or 'very satisfied' between the two groups (88.5% in the neutral alignment group vs. 42.9% in the outlier group, p =0.0088). There was also a significant difference in JKOM total scores between the two groups (24.7 ± 20.4 in the neutral alignment group vs. 47.0± 26.1 in the outlier group, p < 0.0344). The Pearson correlation coefficient between tibial coronal alignment and JKOM score was significant (r = 0.4160, p = 0.0160).

Conclusion: In posterior-stabilized primary TKA, significantly inferior outcomes were detected in the tibial coronal alignment outlier group.

#6162

Functional Prognosis of Total Knee Arthroplasty in Osteoporotic Elderly Patients.

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Background

Recently, a larger number of elderly individuals with osteoporosis has undergone total knee arthroplasty (TKA). Intuitively, such vulnerable bone condition should deteriorate post-TKA functional recovery compared to a non-osteoporotic condition, but this hypothesis has not been directly examined.

Methods

To address this issue, we analysed prognosis of patients who underwent TKA in Toranomon Hospital in Japan between April 2016 and March 2017 (27 of 40 cases, age 75.0±8.2 years old, BMI 24.5±3.1), and evaluated effects of osteoporosis on the changes in functions of the knees three/six/twelve months after the operation. The knee functions were quantified based on Knee Society Score (KSS), and the severity of the pre-operative osteoporosis was evaluated by T-score. We examined the relationships between these scores using multiple regression analyses with age, BMI, and sex as covariates. We excluded patients with rheumatoid arthritis.

Results

The multiple regression analyses revealed that the severity of osteoporosis (T-score) before TKA did not have sufficient explanatory powers for either type of KSS (for Knee Score, adjusted $R2 \leq 0.16$; for Functional Score, adjusted $R2 \leq 0.15$). In addition, Pearson correlation coefficients between the pre-operative osteoporosis severity and KSS were weak (for Knee Score, $|r| < 0.07$, $P > 0.78$; for Functional Score, $|r| < 0.27$, $P > 0.21$; Fig 1). This tendency was qualitatively preserved even when we repeated these analyses for each sex group.

Conclusions

These analyses suggest that counterintuitively, pre-operative osteoporosis does not significantly deteriorate the functional outcome of TKA in the elderly population. Although longer observations of larger samples will be needed, the current findings indicate the possibility that we may not have to hesitate over TKA even for osteoporotic patients.

Figures

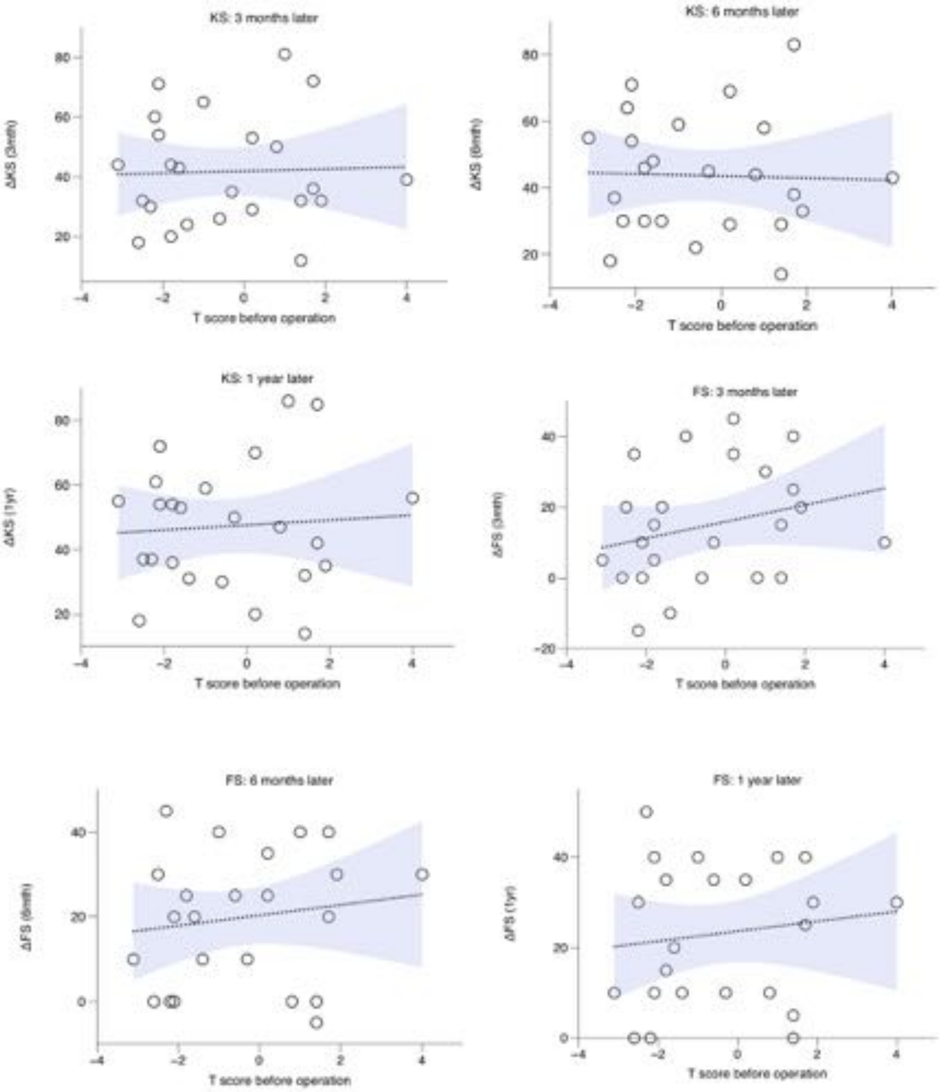
KS: 3 months later
ΔKS (3mth)
T score before operation
KS: 6 months later
ΔKS (6mth)
T score before operation
KS: 1 year later
ΔKS (1yr)
T score before operation
FS: 3 months later
ΔFS (3mth)
T score before operation
FS: 6 months later
ΔFS (6mth)
T score before operation
FS: 1 year later
ΔFS (1yr)
T score before operation

Figure 1

#5966

The Effects of Knee Swelling and Pain on Early Patients Outcomes After Primary Total Knee Arthroplasty

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Background: Total knee arthroplasty (TKA) is offered to patients who have end-stage knee osteoarthritis to reduce pain and improve functional performance. Knee edema and pain deteriorate the patients' outcomes after TKA at early period. By quantifying the patients' early outcome deficits and their potential relationships to edema and pain may assist in the design of in-patient rehabilitation programs.

Objectives: The aim of this study was to investigate of the effect of knee swelling on early patients' outcomes after primary TKA.

Design and Methods: The study group consisted of 61 patients (10 males, 51 females), who underwent primary TKR because of knee arthrosis were included in the study with mean age 65.2±9 years. Patients were evaluated regarding knee circumference (10 cm superior of midpoint of patella, midpoint of patella, 10 cm distal of midpoint of patella), pain (Numeric Pain Rating Scale (NPRS)), knee range of motion (ROM), the day of active straight leg raise, knee function score (Hospital for Special Surgery (HSS)), Functional activities were evaluated using the Iowa Level of Assistance Scale (ILAS) and walking speed was evaluated using the Iowa Ambulation Velocity Scale (IAVS).

Results: There were moderate significant correlation between knee circumference (10 cm superior of midpoint of patella; $r=0.328$, $p=0.001$, midpoint of patella; $r=0.310$, $p=0.002$, 10 cm distal of midpoint of patella; $r=0.300$, $p=0.003$) and IAVS. While, significant low correlation was found between pain level and knee ROM ($r=-0.272$, $p=0.008$), there was strong significant correlation between pain level and HSS ($r=0.866$, $p<0.001$). There was not significant correlation between knee swelling and all the other measurement, and also between pain and all the other measurement ($p>0.05$).

Conclusion: The moderate correlation between knee swelling and IVAS, low correlation between pain and knee ROM, and also strong correlation between pain and HSS suggests that improved postoperative knee swelling and pain could be important to enhance the potential benefits of TKA in early stage. With improvement in knee swelling and pain the patient may obtain good functional outcomes and knee score.

Key words: Knee Swelling, Pain, Total Knee Replacement, Early Outcomes.

A Mid-Term Follow-Up Study of Quality of Life After Bilateral Total Knee Arthroplasty

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Introduction: Patient self-reported outcome scales have recently been used to evaluate total knee arthroplasty (TKA) outcomes. Many follow-up studies have been conducted on patients undergoing TKA; however, they have mostly reported outcomes after unilateral TKA. We believe that a longitudinal study after bilateral TKA will be more useful in evaluating the quality of life (QOL) of such patients.

Objectives: The objective of this study was to longitudinally evaluate QOL using the Japanese Knee Osteoarthritis Measure (JKOM). Objective outcomes were assessed using the Knee Society Score (KSS) and the Timed Up and Go test (TUG) for more than 5 years after bilateral TKA. Furthermore, QOL and objective outcomes were compared between younger (age ≤ 80 years at the final follow-up point) and older (age > 80 years) age groups.

Methods: In total, 109 patients underwent two-staged bilateral TKAs for varus knee osteoarthritis at our clinic between October 2006 and March 2013. Of these patients, 78 were evaluated preoperatively (Pre) and at 1, 3 and 5 years or more (average, 6.7 years; range, 5–10 years) after bilateral TKAs using JKOM, KSS and TUG. The average patient age at the time of the first and the contralateral TKAs was 73.3 (range, 61–85) years and 74.0 (range, 62–85) years, respectively. The average patient age at the final follow-up point among younger (36 patients) and older (42 patients) age groups was 75.8 (range, 67–80) years and 84.7 (range: 81–92) years, respectively. The outcomes at each evaluation point were compared using Steel–Dwass test. A comparison of the JKOM scores and objective outcomes between the younger and older age groups was performed using Mann–Whitney U-test. P values < 0.05 were considered significant.

Results: A significant improvement in the JKOM score was observed between ‘Pre’ and ‘1 year after bilateral TKA’; the improvement was maintained until the final follow-up point (Fig. 1). All four subscales in JKOM showed the same improvement as JKOM itself. Furthermore, significant improvements in the total KSS, knee and function scores were observed between ‘Pre’ and ‘1 year after bilateral TKA’; the improvement was maintained until the final follow-up point. A significant improvement in the TUG scores was observed between ‘Pre’ and ‘1 year after bilateral TKA’; although the improvement was maintained for 3 years, there was a small but significant deterioration at the final follow-up point (Fig. 2). Although the average age difference between the two groups was 8.9 years, no significant differences were found in the JKOM and objective outcome scores between the younger and older age groups.

Conclusions: This is the first longitudinal mid-term follow-up study to evaluate QOL after bilateral TKAs. The JKOM and objective outcome scores reached a plateau 1 year after bilateral TKA, and the improvement was maintained for an average of 6.7 years; however, TUG scores showed a small deterioration at the final follow-up point. The improvement in the JKOM and objective outcome scores maintained by the older age

group was equivalent to that by the younger one.

#6073

Ability of Walking After Total Knee Arthroplasty Is Correlated With Preoperative Berg Balance Scale

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Regaining the walking ability is one of the main purposes of total knee arthroplasty (TKA). Improving the activities of daily living is a key of patient satisfaction after TKA. However, some patients do not gain enough improvement of ADL as they preoperatively expected, and thus are not satisfied with the surgery. The purpose of this study is to clarify the relationship between preoperative and postoperative physical functional status and whether preoperative scoring can predict the postoperative walking ability. Consecutive 136 patients who underwent total knee arthroplasty for osteoarthritis were prospectively assessed. The average age (±SD) was 74±7.7 and 74% of the patients was female. Berg Balance Scale (BBS) was assessed preoperatively and one year after the surgery. The time needed for 10m walking, muscle power for knee extension and flexion, visual analog scale (VAS) for pain in walking, and necessity of canes in walking were also assessed at one year after the surgery. Multivariate correlation analysis was performed for each parameter. Speaman rank correlation coefficient revealed that preoperative BBS was significantly correlated with the time needed for 10m walking ($\rho=0.66$, $p<0.001$). Logistic regression analysis also revealed that preoperative BBS is also correlated with the necessity for canes in walking one year after the surgery. The cut-off value of preoperative BBS for the necessity of canes in walking by ROC curve analysis was 48 points with 79% in sensitivity and 80% in specificity. The muscle powers were also weakly correlated with the walking ability at one year after the surgery, but VAS for pain was not. The study indicated that preoperative physical balance could predict the ability of walking one year after TKA regardless of the reduction of pain. It is suggested that surgery should be recommended before the physical balance function deteriorates to achieve the better walking ability after the TKA

#5517

Missed Pathology- Is This the Cause of Unhappy TKR Patient?

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Introduction and aim: TKR remains one of the most successful surgeries in orthopedics a sizeable number of patients still remain dissatisfied reaching to a level of 30% our aim was to examine the excised the synovium from the suprapatellar region in all osteoarthritic knees and evaluate the histopathological report to know if in a few cases the unrelenting pain and discomfort could be due to some undiagnosed pathology within the joint.

Material and methods: we selected 40 consecutive knees at our institution operated from Oct 2014 to Jan 2015 of the total knees 7 patients were operated as single stage bilateral knees supra patellar synovial was thoroughly excised and sent for histopathology patient who were clinically serologically and radiological diagnosed as rheumatoid arthritis or sero negative arthritis were excluded.

Result: We found abnormal reports in 8 of our 40 knees (20%) 6 of these were proven to be rheumatoid arthritis whilst 2 of the knees showed chronic villous synovitis.

Conclusion: 20% of our patients exhibited result which were totally unexpected this could be one of the many cause in persistently dissatisfied patient after a technically well done TKR so as a routine we advocate all surgeons to send the excised synvoium for histopathology during a routine TKR also a large multicentric study undertaken at various centers would definitely help throw more light on this not so well understood topic and thus help reduce this lot of dissatisfied patient.

#6193

Patellofemoral Arthroplasty Improves Gait in Isolated Patellofemoral Arthritis, a Prospective Cohort Gait Analysis Study.

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Introduction

Patellofemoral osteoarthritis (PFOA) affects 32% men and 36% women over the age of 60years and is associated with anterior knee pain, stiffness, and poor mobility. Patellofemoral arthroplasty (PFA) is a bone-sparing treatment for isolated PFOA(1). This study set out to investigate the relationship between patient-related outcome measures (PROMs) and measurements obtained from gait analysis before and after PFA. There are currently no studies relating to gait analysis and PFA available in the literature

Research Question

Does PFA improve patient reported outcome measures (PROMs) and restore normal gait

Methods

A prospective cohort study was conducted of ten patients known to have isolated PFOA who had undergone PFA compared to a gender and age matched control group. The patients were also asked to complete questionnaires (Oxford knee score (OKS), EQ-5D-5L) before surgery and one year after surgery(2). Gait analysis was done on an instrumented treadmill comparing Ground reaction force parameters between the control and pre and post-operative PFA patients

Results

The average age 60 (49-69) years with a female to male ratio of 9:1. Patient and healthy subjects were matched for age and gender, with no significant difference in BMI.

Post-op PFA improvement in gait can be seen in ground reaction force at 6.5km/h (Fig.1). Base support difference between control and pre-op group was statistically significant both on the flat P=0.0001 and uphill P=0.429 (5% inclination) and P=0.0062 (10% inclination). Uphill gait at 15% (fig.3) shows post op gait improvements.

PROMS response rate was 70%(7/10) pre-operative and 60%(6/10) post-operative. EQ-5D-5L scores reflected patient health state was better post-operatively

Discussion

This study found that gait analysis provides an objective measure of functional gait (Fig.1) and reflected by significant improvement in quality of life of patients post PFA.

Current literature discusses positive outcomes in relation to physiological gait patterns, normalised gait-analysis parameters and PROMs in total knee arthroplasty(2). Literature lacks studies relating to gait-analysis and PFA. Valuable information provided by this study highlights that PFA has a beneficial outcome reflected by PROMs and improvement in vertical ground reaction force (Fig.1) and gait uphill (Fig.3).

Further research and studies are needed to assess how care-providers may use gait-analysis as part of patient care plans for PFOA patients

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3.Arazpour M, Bahramian F, Abutorabi A, Nourbakhsh ST, Alidousti A, and Aslani H. The Effect of Patellofemoral Pain Syndrome on Gait Parameters: A Literature Review. Arch Bone Jt Surg. 2016; 4(4): 298–306

Figures

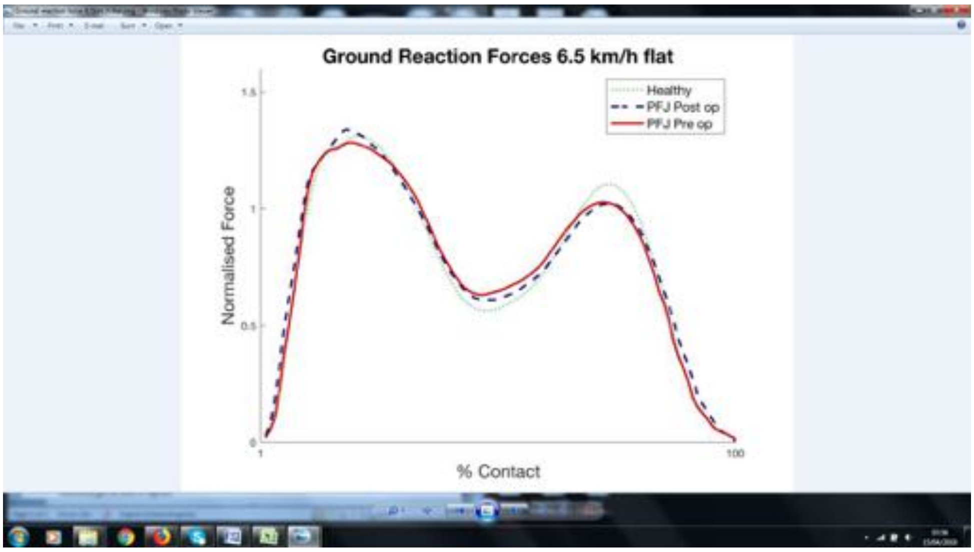

Figure 1

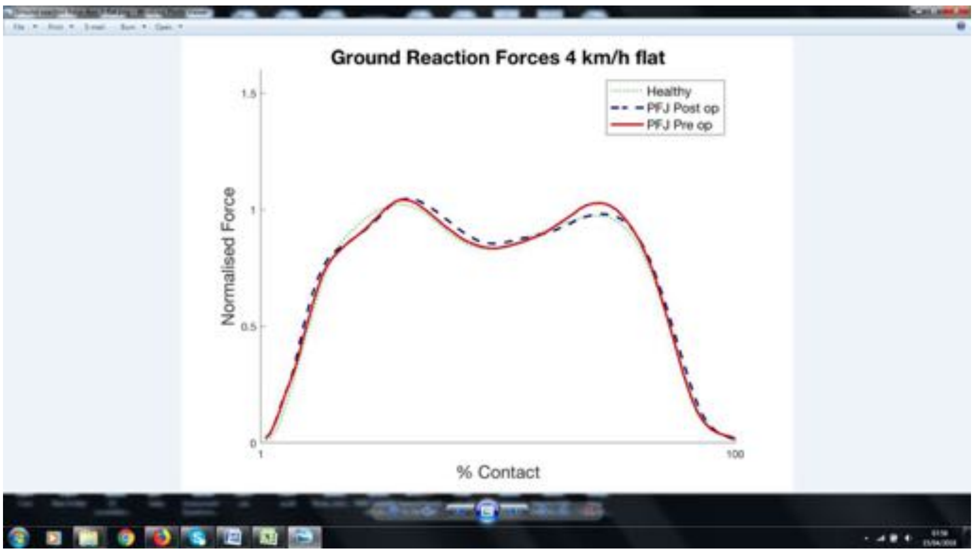

Figure 2

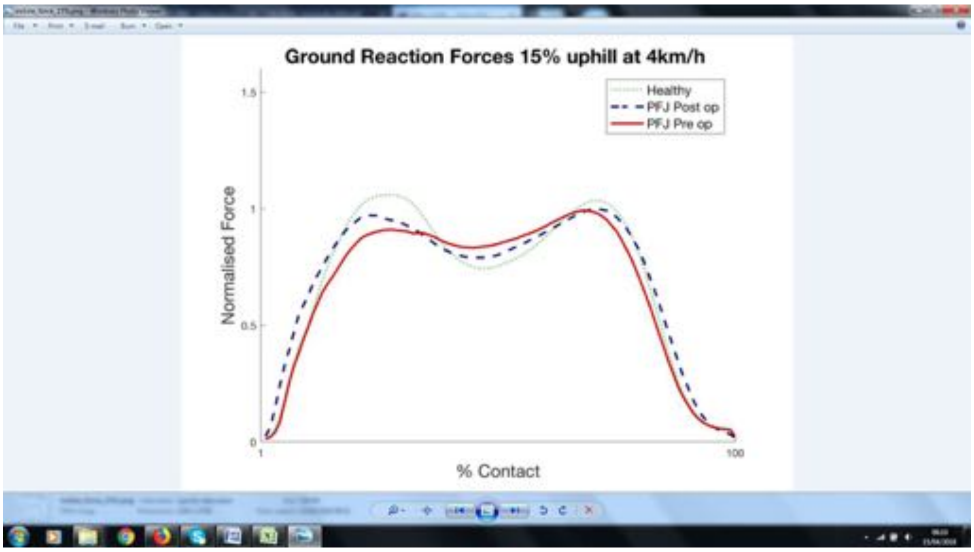
Ground Reaction Forces 15% uphill at 4km/h
Healthy
PFJ Post op
PFJ Pre op
Normalised Force
1.5
1
0.5
0
1
100
% Contact

Figure 3

#5603

Lower Knee Score but Better Survival of Mobile Bearing TKAs When Patella Is Resurfaced: A Matched-Paired Retrospective Study.

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OBJECTIVES

The use of a mobile bearing has been suggested to decrease the rate of patellar complications after total knee arthroplasty (TKA). However, to resurface or retain the native patella remains debated. Few long-term results have been documented. The present retrospective study was designed to evaluate the long-term (more than 10 years) results of mobile bearing TKAs on a national scale, and to compare pain results and survivorship according to the status of the patella.

The primary hypothesis of this study was that the 10 year survival rate of mobile bearing TKAs with patella resurfacing will be different from that of mobile bearing TKAs with native patella retaining.

METHODS

All patients operated on between 2001 and 2004 in all participating centers for implantation of a TKA (whatever design used) were eligible for this study. Usual demographic and peri-operative items have been recorded. All patients were contacted after the 10 year follow-up for repeat clinical examination (Knee Society score (KSS), Oxford knee questionnaire). Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information about prosthesis survival. TKAs with resurfaced patella and TKAs with retained native patella were paired according to age, gender, body mass index and severity of the coronal deformation (with steps of 5°). Pain score, KSS and Oxford knee score were compared between two groups with a Student t-test at a 0.05 level of significance. Survival curve was plotted according to the actuarial technique, using the revision for mechanical reason as end-point. The influence of the patella status was assessed with a logrank test at a 0.05 level of significance.

RESULTS

1,604 TKAs were implanted during the study time-frame. 849 cases could be paired according to age, gender, BMI and severity of the pre-operative coronal deformation (2/1 ratio) into two groups: resurfaced patella (496 cases) and retained patella (243 cases). There was no difference in any baseline criteria between both groups. 150 patients deceased before the 10 year follow up (18%). Final follow-up was obtained for 489 cases (58%). 31 reoperations (prosthesis exchange or patellofemoral revision) were performed during the study time frame (4%), with 17 reoperations for mechanical reasons (3%). KSS and Oxford knee score were significantly higher for TKAs without patella resurfacing, There was a significant difference between the 13 year survival rates of TKAs with resurfaced patella (97%) and TKAs with retained native patella (93%).

CONCLUSIONS

The primary hypothesis was confirmed: 10 year survival rate of mobile bearing TKAs with patella resurfacing was better than mobile bearing TKAs with native patella retaining. Patella resurfacing may lead to a better survival after mobile bearing TKA. However, the clinical results were better after patella resurfacing when the index TKA was not revised.

#5625

Returning to Work After Journey II Total Knee Replacement

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Background:

With a rise in state pension age to 67 years (Pensions Act 2014) in United Kingdom and about 51% patients having their total knee replacement before the age of 70 (NJR 2016), many may have surgery whilst in employment. Information regarding if and when they return to work may be of value in the shared decision making process.

Method:

We prospectively assessed the first 200 patients who received a *Journey II* TKR (Smith and Nephew, Memphis, USA) between July 2013 and October 2015, analysing pre- and post-operative outcome scores and return to employment.

Results:

Forty seven out of 55 patients (85.4%) who were in employment pre-operatively returned to work post-operatively at a mean time of 15.4 weeks. Five in the medium and three in the heavy work preoperatively did not return to work whilst all patients doing light work preoperatively returned to work. Those in light, moderate and heavy work returned to work at 11.8, 18 and 17 weeks respectively. No patient not working pre-operatively, re-commenced work post-operatively. In both employed and not employed groups, there was significant improvement in SF-12 (physical), WOMAC and Oxford scores post-operatively. Those in employment had significantly better pre-operative SF-12 (mental), WOMAC and Oxford scores than those not in employment but whilst both groups improved, those returning to employment maintained significantly better scores.

Conclusions:

Majority of the employed patients return back to employment after Journey II TKR. Employed patients have better pre-operative scores; whilst both groups improve, those in employment gain higher post-operative scores.

#5759

Impact of Screw Preload on Primary Stability in Reverse Shoulder Arthroplasty

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INTRODUCTION

Finite element analysis (FEA) is widely used to study micromotion between the glenoid baseplate and bone, as a pre-clinical indicator for clinical stability in reverse total shoulder arthroplasty (rTSA). Various key parameters such as the number, length, and angle of screws have been shown to influence micromotion [1]. This study explores the influence of screw preloads, an insufficiently studied parameter. Specifically, two rTSA configurations with 18mm and 48mm peripheral screws (PS) were analyzed without screw preloads, followed by analysis of the 48mm PS configuration with an experimentally measured screw preload.

METHODS

FEA models were created to simulate a fixation experiment inspired by ASTM F2028-14. The rTSA configurations used here have a superior and an inferior PS. The assemblies were virtually implanted into a synthetic bone block as per surgical technique. Sliding contacts were defined to model the interface between screw threads-bone, and between baseplate-bone.

To determine the screw preload experimentally, the 48mm screw (n=5) was inserted through a hole in a metal plate, which rested on top of a Futek washer load cell, placed on top of the foam block with a predrilled pilot hole (Figure 1). The screw was inserted using a torque driver until the average human factors torque for the screw driver handle was reached. The resulting axial compressive load due to screw insertion was measured by the washer load cell.

Two step analyses were performed using Ansys version 17.2 for 18mm and 48mm PS, where 756N axial and shear loads were applied sequentially. The model with the 48mm PS was then analyzed in a four step analysis; preload inferior and superior screws, followed by applying the axial and shear loads (Figure 2). Peak overall micromotion including tangential and normal components at the baseplate-bone interface was compared for all three models.

RESULTS

From the experimental study, the mean screw preload for the 48mm screw was determined to be 141±8 lbs. Peak micromotion was predicted at the inferior edge of the baseplate (Figure 3A). In the two models without screw preloads, the model with the 48mm PS predicted 42% lower micromotion than the model with the 18mm PS. The 48mm PS model predicted 63% further reduction in micromotion by including the preload for the two PS. Figure 3B presents the micromotion comparison between these three models.

DISCUSSION

This study demonstrates the significant influence that screw preload can have on evaluating either absolute values or differential performance of rTSA micromotion within the same design family. It further demonstrated that the inclusion of preload in simulation can have as much (or greater) impact on micromotion as other key parameters such as shorter versus longer screws. These findings indicates that it is important to include appropriate values of screw preloads in simulations when comparing designs with different number of peripheral screws or studying the effects of including a central screw on rTSA micromotion.

REFERENCES

[1]. Hopkins et al, Proc. IMechE Vol. 223 Part H: J. Engineering in Medicine, 2009.

Figures

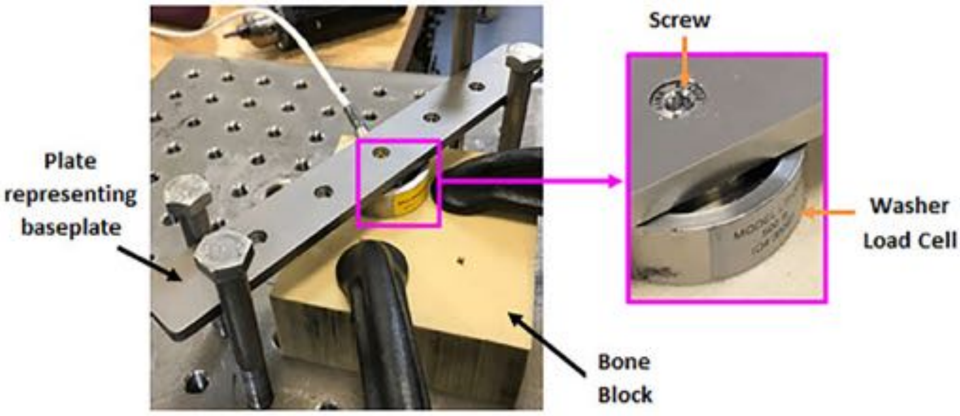

Figure 1. Experimental setup to measure screw preload
Figure 1

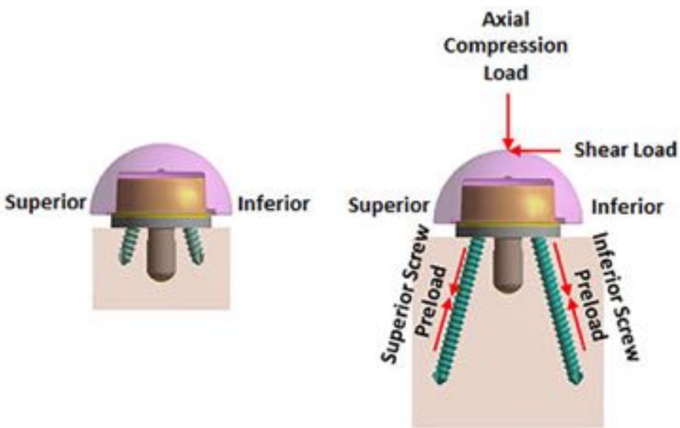

Figure 2. FE model in anterior-posterior view: (left) 18mm PS (right) 48mm PS with applied loads
Figure 2

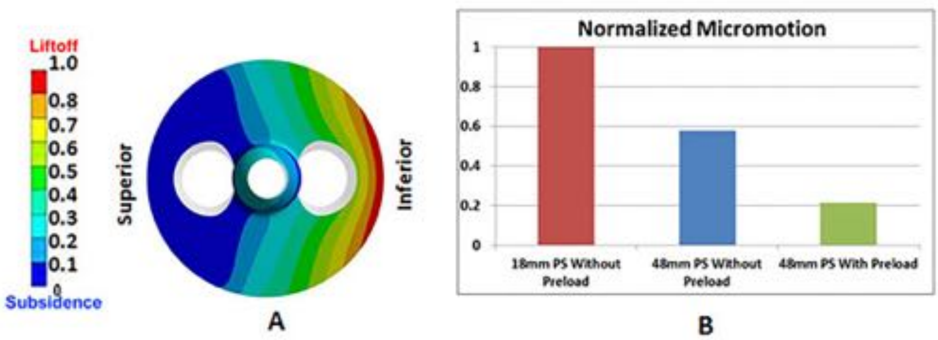

Figure 3. A. Normalized baseplate micromotion using 18mm screw model without preload (shown here from distal view). B. Normalized peak micromotion comparison for three models
Figure 3

#5604

Evaluation of Implant Fixation in Reverse Total Shoulder Arthroplasty: A Prospective, Randomized Clinical Trial

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Introduction: Total shoulder arthroplasty is the fastest growing joint replacement in recent years, with projected compound annual growth rates of 10% for 2016 through 2021 – higher than those of both the hip and knee combined. Reverse total shoulder arthroplasty (RTSA) has gained particular interest as a solution for patients with irreparable massive rotator cuff tears and failed conventional shoulder replacement, for whom no satisfactory intervention previously existed. As the number of indications for RTSA continues to grow, so do implant designs, configurations, and fixation techniques. It has previously been shown that continuous implant migration within the first two years postoperatively is predictive of later loosening and failure in the hip and knee, with aseptic loosening of implant components a guaranteed cause for revision in the reverse shoulder. By identifying implants with a tendency to migrate, they can be eliminated from clinical practice prior to widespread use. The purpose of this study is to, for the first time, evaluate the pattern and magnitude of implant component migration in RTSA using the gold standard imaging technique radiostereometric analysis (RSA).

Methods: Forty patients were prospectively randomized to receive either a cemented or press-fit humeral stem, and a glenosphere secured to the glenoid with either autologous bone graft or 3D printed porous titanium (Aequalis Ascend Flex, Wright Medical Group, Memphis, TN, USA) for primary reverse total shoulder arthroplasty. Following surgery, partients are imaged using RSA, a calibrated, stereo x-ray technique, at 6 weeks (baseline), 3 months, 6 months, 1 year, and 2 years. Migration of the humeral stem and glenosphere at each time point is compared to baseline. Preliminary results are presented, with 15 patients having reached the 6-month time point by presentation.

Results: Implant migration of ten participants at the 3-month time point is presented. Maximum total point motion (MTPM) is a measure of translation and rotation of the point on the implant that has moved the most from baseline. Average MTPM ± SD of the humeral stem is 1.18 ± 0.65 mm and 0.98 ± 0.46 mm for press-fit (n = 6) and cemented (n = 4) stems, respectively; and 0.25 ± 0.09 mm and 0.47 ± 0.24 mm for bone graft (n = 4) and porous titanium (n = 6) glenosphere fixations, respectively, at the 3-month time point.

Conclusion: There is a trend towards increased migration with the use of press-fit humeral stems and porous titanium glenosphere fixation, though no conclusions can be made from the current sample size. Further, though differences in migration magnitude may be observed at early postoperative time points, it is expected that all fixation techniques will show stability from 1 to 2 years postoperatively.

#5768

Effect of Screw Length and Screw Number on Reverse Shoulder Glenoid Fixation

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Introduction

Aseptic glenoid loosening is a common failure mode of reverse shoulder arthroplasty (rTSA). Achieving initial glenoid fixation can be a challenge for the orthopedic surgeon since rTSA is commonly used in elderly osteoporotic patients and is increasingly used in scapula with significant boney defects. Multiple rTSA baseplate designs are available in the marketplace, these prostheses offer between 2 and 6 screw options, with each screw hole accepting a locking and/or compression screw of varying lengths (between 15 to 50mm). Despite these multiple implant offerings, little guidance exists regarding the minimal screw length and/or minimum screw number necessary to achieve fixation. To this end, this study analyzes the effect of multiple screw lengths and multiple screw numbers on rTSA initial glenoid fixation when tested in a low density (15pcf) polyurethane bone substitute model.

Methods

This rTSA glenoid loosening test was conducted according to ASTM F 2028-17; we quantified glenoid fixation of a 38mm reverse shoulder (Equinoxe, Exactech, Inc) in a 15 pcf low density polyurethane block (Pacific Research, Inc) before and after cyclic testing of 750N for 10k cycles. To evaluate the effect of both screw fixation and screw number, glenoid baseplates were constructed using 2 and 4, 4.5x18mm diameter poly-axial locking compression screws (both n = 5) and 2 and 4, 4.5x46mm diameter poly-axial locking compression screws (both n = 5). A two-tailed unpaired student's t-test ($p < 0.05$) compared prosthesis displacements to evaluate each screw length (18 vs 46mm) and each screw number (2 vs 4).

Results

All glenoid baseplates remained well-fixed after cyclic loading in the low density bone substitute block, regardless of screw length or screw number. As described in Table 1, the average pre- and post-cyclic displacement for baseplates with 18mm long screws was significantly greater than that of baseplates with 46mm long screws in both the A/P and S/I directions, with exception of displacements for 4 screws S/I-pre cyclic and 2 screws A/P-post cyclic loading. As described in Table 2, the average pre- and post-cyclic displacement for all baseplates with 2 screws was significantly greater than that of all baseplates with 4 screws, regardless of screw length in the A/P and S/I directions.

Discussion and Conclusions

These results of this study demonstrate that rTSA glenoid baseplate fixation is impacted by both the number of screws and by the length of screws, with longer screws and more screws associated with significantly better initial fixation. However, it should be noted that none of the tested devices catastrophically failed in this non-defect/low-density model, demonstrating that adequate fixation can be achieved with as little as 2x18mm screws for some baseplate types. Care should be made when extrapolating these results to that of other designs. This study is limited by its use of only one implant design and by its use of a polyurethane substrate without any defect; future work should evaluate the effect of screw length and screw number in with multiple different prostheses in different densities of bone with and without defects.

Figures

Table 1. Effect of Screw Length on rTSA glenoid baseplate displacement before and after cyclic loading in a 15pcf bone substitute substrate

Baseplate Shear Displacement in (microns)	SI Shear Pre	SI Shear Post	AP Shear Pre	AP Shear Post
2x18mm Screws	159 ± 2.9	171 ± 3.4	312 ± 4.6	337 ± 3.6
2x46mm Screws	86 ± 1.1	79 ± 0.6	177 ± 1.2	268 ± 1.5
P Value	**0.0002**	**0.0005**	**0.0118**	0.3272
4x18mm Screws	73 ± 0.7	94 ± 1.0	118 ± 3.1	141 ± 1.0
4x46mm Screws	64 ± 0.9	64 ± 0.6	79 ± 1.0	93 ± 1.0
P Value	0.1040	**0.0020**	**0.0022**	**0.0104**

Figure 1

Table 2. Effect of Screw Number on rTSA glenoid baseplate displacement before and after cyclic loading in a 15pcf bone substitute substrate

Baseplate Shear Displacement in (microns)	SI Shear Pre	SI Shear Post	AP Shear Pre	AP Shear Post
2x18mm Screws	159 ± 2.9	171 ± 3.4	312 ± 4.6	337 ± 3.6
4x18mm Screws	73 ± 0.7	94 ± 1.0	118 ± 3.1	141 ± 1.0
P Value	**<0.0001**	**0.0020**	**0.0015**	**0.0015**
2x46mm Screws	86 ± 1.1	79 ± 0.6	177 ± 1.2	268 ± 1.5
4x46mm Screws	64 ± 0.9	64 ± 0.6	79 ± 1.0	93 ± 1.0
P Value	**0.0253**	**0.0013**	**<0.0001**	**0.0127**

Figure 2

Articular Impingement in Reverse Shoulder During Activities of Daily Living: A Biomechanical Analysis With the SMR Prosthesis

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Introduction

Reverse Shoulder Arthroplasty (RSA) is recognized to be an effective solution for rotator cuff deficient arthritic shoulders, but there are still concerns about impingement and range of motion (ROM). Several RSA biomechanical studies have shown that humeral lateralization can increase ROM in planar motions (e.g. abduction). However, there is still a debate whether humeral lateralization should be achieved with a larger sphere diameter or by lateralizing the center of rotation (COR). The latter has shown to decrease the deltoid moment arm and increase shear forces, where the former may pose challenges in implanting the device in small patients. The aim of this study was to evaluate how humeral lateralization achieved by varying COR lateral offset and glenosphere diameter in a reverse implant can affect impingement during activities of daily living (ADLs).

Methods

Nine shoulder CT scans were obtained from healthy subjects. A reverse SMR implant (LimaCorporate, IT) was virtually implanted on the glenoid and humerus (neck-shaft angle 150°) as per surgical technique using Mimics software (Materialise NV). Implant positioning was assessed and approved by a senior surgeon. The 3D models were imported into a validated shoulder computational model (Newcastle Shoulder Model) to study the effects of humeral lateralization, fig.1. The main design parameters considered were glenosphere diameter (concentric Ø36mm, Ø40mm, Ø44mm) and COR offset (standard, +2mm, +5mm), for a total of 9 combinations for each subject; -10°, 0° and 10° humeral components versions were analyzed. The model calculated the percentage of impingement (intra-articular, contact of cup with scapula neck and glenoid border; extra-articular, contact of humerus with acromion and coracoid) during 5 ADLs (hand to opposite shoulder, hand to back of head, hand to mouth, drink from mug and place object to head height).

Results

Average overall impingement along each ADLs cycle, for each glenosphere and lateralization offset, are shown in fig. 2. On average, the Ø40mm and Ø44mm glenosphere resulted in significantly less impingement across ADLs. Especially for Ø44mm, humeral version and lateralization had little effect on impingement. For the Ø36mm, a lateralization of +5 mm substantially reduced impingement only with 0° and 10° anteversion while, conversely, did not reduce the impingement with 10° retroversion.

Discussion and Conclusions

The results of this study suggest that, for the SMR Reverse prosthesis, humeral lateralization through the increase of glenosphere diameter was the most efficient way to reduce impingement during ADLs compared to the lateralization of the COR. Humeral version can also affect the impact of lateralization on impingement during ADLs; in this study, the impingement for the Ø36mm glenosphere with 10° retroversion was not decreased through lateralization; this may be related to the combined effect of version and scapular morphology (fig. 3). Considering that using larger glenosphere diameter without offsetting the COR theoretically does not reduce overall deltoid lever arm nor increase the shear forces on the glenoid component, this should be the preferable option whenever possible. However, concerns over soft tissue over-tensioning may necessitate the use of a smaller diameter glenosphere in some patients.

Figures

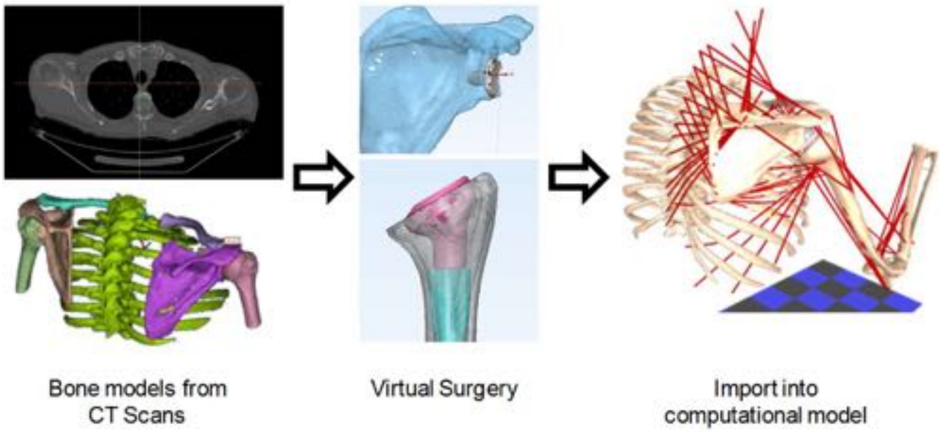

Fig. 1: Modelling process and import into Newcastle Shoulder Model

[Figure 1](#)

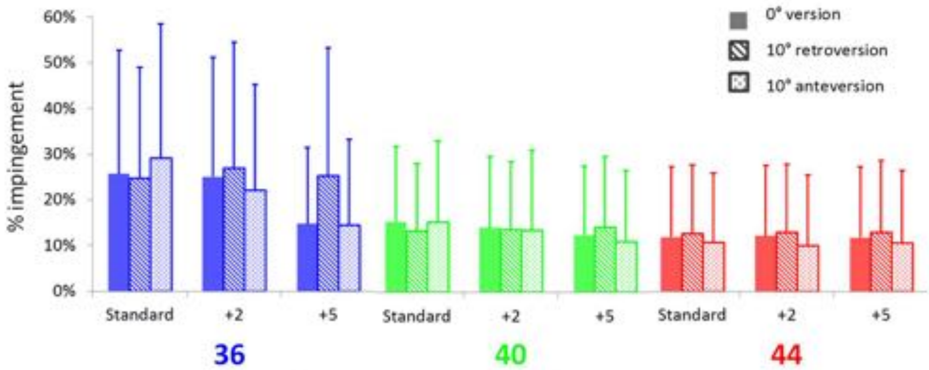

Fig. 2: Average combined intra and extra articular impingement along ADLs

[Figure 2](#)

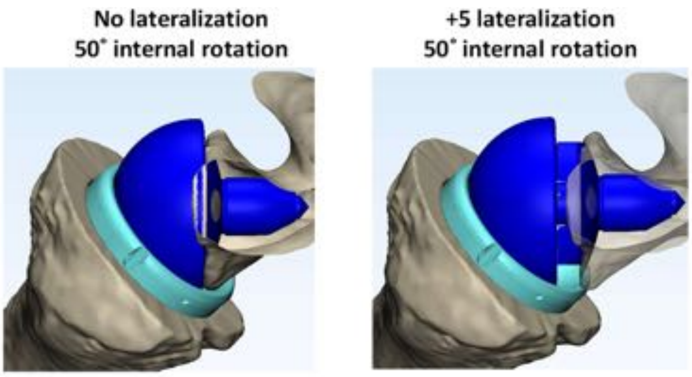

Fig. 3: Impingement detection during simulated internal rotation with no lateralization and +5 mm lateralization with a 36mm glenosphere

[Figure 3](#)

#6158

Cuff Tear Arthropathy: Determination of Predisposing Scapular Anatomy With a Statistical Shape Model.

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Background

Degeneration of the shoulder joint is a frequent problem. There are two main types of shoulder degeneration: Osteoarthritis and cuff tear arthropathy (CTA) which is characterized by a large rotator cuff tear and progressive articular damage. It is largely unknown why only some patients with large rotator cuff tears develop CTA (Ecklund *et al.*, 2007). In this project, we investigated CT data from 'healthy' persons and patients with CTA with the help of 3D imaging technology and statistical shape models (SSM). We tried to define a native scapular anatomy that predesignate patients to develop CTA.

Methods

Statistical shape modeling and reconstruction:

A collection of 110 CT images from patients without glenohumeral arthropathy or large cuff tears was segmented and meshed uniformly to construct a SSM. Point-to-point correspondence between the shapes in the dataset was obtained using non-rigid template registration. Principal component analysis was used to obtain the mean shape and shape variation of the scapula model. Bias towards the template shape was minimized by repeating the non-rigid template registration with the resulting mean shape of the first iteration.

Shape reconstruction was performed similarly to the procedure described by Vanden Berghe *et al.* (2016). This method has been used to reconstruct the glenoid surface, version and inclination can be predicted with an accuracy of 3.0 and 2.7 degrees respectively (Plessers *et al.*, 2018). Eighty-six CT images from patients with different severities of CTA were analyzed by an experienced shoulder surgeon and classified following Hamada *et al.* (2011). CT images were segmented and inspected for signs of glenoid erosion. Remaining healthy parts of the eroded scapulae were partitioned and used as input of the iterative reconstruction algorithm. During an iteration of this algorithm, 30 shape components of the shape model are optimized and the reconstructed shape is aligned with the healthy parts. The algorithm stops when convergence is reached.

Measurements:

Automatic 3D measurements were performed for both the healthy and reconstructed shapes, including glenoid version, inclination, offset and critical shoulder angle. These measurements were manually performed on the mean shape of the shape model by a surgeon, after which the point-to-point correspondence was used to transfer the measurements to each shape.

Results

Figure 1 gives an overview of the measurements on the reference scapulae and the 86 scapulae from CTA patients. The critical shoulder angle was found to be significantly larger for the CTA scapulae compared to the references (P<0.01). When analysing the classified scapulae (Figure 2), significant differences were found for the version angle in the scapulae of group 4a/4b and the critical shoulder angle of group 3 when compared to the references (P<0.05).

Conclusion

Patients with CTA have a larger critical shoulder angle compared with reference patients. Some significant differences are found between the scapulae from patients in different stages of CTA and healthy references, however the differences are smaller than the accuracy of the SSM reconstruction. Therefore, we are unable to conclude that there is a predisposing anatomy in terms of glenoid version, inclination or offset for CTA.

Figures

Figure 1: Measurements for reference scapulae and the 86 scapulae with cuff tear arthropathy (Bold: P<0.05).

	References (N=110)	CTA (N=86)
Version (°)	-4.7 ± 3.8	**-5.7 ± 2.9**
Inclination (°)	5.9 ± 3.8	6.2 ± 3.8
Critical Shoulder Angle (°)	30.4 ± 3.8	**32.6 ± 3.9**
Glenoid offset (mm)	105.9 ± 8.6	105.1 ± 7.5

Figure 1

Figure 2: Measurements for reference scapulae and scapulae classified according to the Hamada progression classification (Bold: P<0.05).

	References	Hamada classification				
		1 (N=7)	2 (N=8)	3 (N=12)	4a & 4b (N=52)	5 (N=7)
Version (°)	-4.7 ± 3.8	-5.1 ± 3.5	-6.7 ± 3.9	-4.1 ± 3.0	**-6.1 ± 2.4**	-5.4 ± 1.5
Inclination (°)	5.9 ± 3.8	4.3 ± 2.5	7.2 ± 4.0	7.1 ± 3.1	6.6 ± 4.6	4.5 ± 2.5
Critical Shoulder Angle (°)	30.4 ± 3.8	31.2 ± 3.7	33.4 ± 4.3	**34.6 ± 3.2**	32.2 ± 4.5	32.7 ± 2.7
Glenoid offset (mm)	105.9 ± 8.6	103.8± 4.4	113.4 ± 10.2	101.4 ± 6.2	104.8 ± 7.5	103.1 ± 5.9

Figure 2

#5548

Developing Robust Non-Invasive Shoulder Biomechanics Analyses of Pre-Operative Reverse Total Shoulder Replacement Patients

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Introduction: Developing robust non-invasive measurement of shoulder is crucial in order to better understand shoulder movement mechanics in vivo and to inform shoulder implant designs. One challenge in understanding shoulder movement mechanics is the difficulty to non-invasively measure scapular motion under stationary skin. Acromion Marker Clusters (AMC) have been developed to create mathematical mapping between anatomically meaningful scapular landmarks and the AMC tracking reference system. Additionally, electromyographic (EMG) measurements need to be normalized to enable meaningful comparisons between muscle groups or subjects. Normalizations using manual muscle tests (MMT) are commonly used. However, using maximal muscle contraction to obtain these reference EMG levels may be difficult, especially when testing pre-operative patients with symptomatic shoulders. The purpose of our ongoing study is to analyze movement and EMG patterns in patients before and after reverse total shoulder replacement during activities of daily living. **Methods:** Three patients with massive rotator cuff tears who were scheduled for reverse total shoulder arthroplasty volunteered in accordance with the IRB to undergo optical motion analysis and EMG measurements during activities of daily living. An AMC was used to track the scapula, after using multiple calibration poses: anatomic stance (“A-pose”) and 90deg scapular-plane humeral elevation “scaption” (assisted, if necessary). Patients were asked to perform scaption with neutral shoulder rotation, external rotation, and internal rotation three times. Additionally, a four-axis humeral dynamics representation previously described was used to calculate humeral dynamics (first isolating and subtracting the humeral internal/ external angular velocity). Muscle activation data were filtered using a butterworth band-pass filter (10-400Hz, 4^{th}-order, zero phase), rectified, and averaged into 20ms “bins”. Muscle activation was normalized to either %MMT or to the within-trial-type maximum bin (“within-task-max”) to account for variability of MMT performance in this clinical population. Time zero indicates when the elbow reached maximum height and was used to synchronize multiple trials. **Results and Discussion:** Fig.1 shows that subject 1 used healthier scapulo-humeral coordination than did other subjects, there was less humeral abduction during the internally-rotated scaption task, and that there were differences in scapular orientation estimates using anatomic pose (solid lines) or 90deg scaption (dotted lines). Specifically, using the anatomic pose underestimated scapular upward rotation vs. using the 90deg scaption pose calibration in subject 1, whereas, subjects 2 and 3 display the opposite trend. In Fig.2, average EMG muscle activation levels are displayed using three different color representations. Using normalization relative to MMT (Fig.2A&B), the deltoid demonstrated lower activity relative to MMT than the upper trapezius in functionally pseudoparalytic patients (subjects 2 and 3). However, when representing the muscle activation relative to within-task-max (Fig.2C), there was a similar range of percent activations across patients (cyan-orange activations). Under or over-estimation of the level of activity could occur when representing data relative to MMT. For example, the deltoids may not be able to perform maximal contraction because of pain and inability to control the typical abducted position used during MMTs. Further study is required to improve AMC scapular calibration methods and EMG normalization, especially in patients with shoulder pain and dysfunction.

Figures

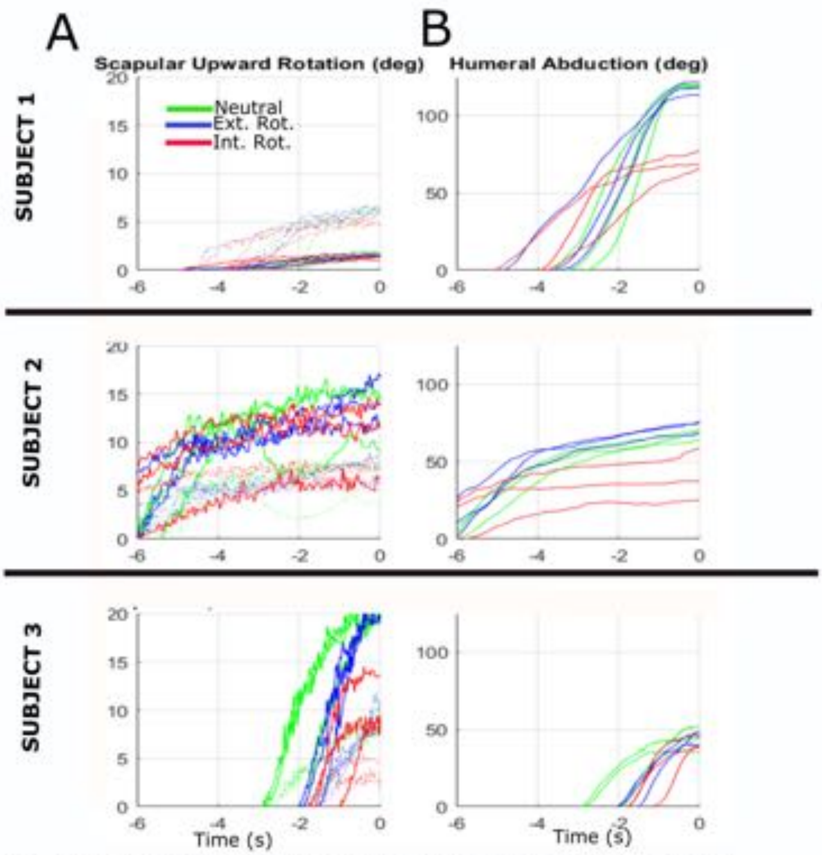

Fig. 1: Approximate scapular upward rotation (A) and humeral abduction (B) displayed during scaption tasks with varied internal/external shoulder rotation. Dotted lines indicate scapular upward rotation estimated using 90deg scaption calibration pose, solid lines indicate scapular upward rotation estimated using anatomic calibration pose.

Figure 1

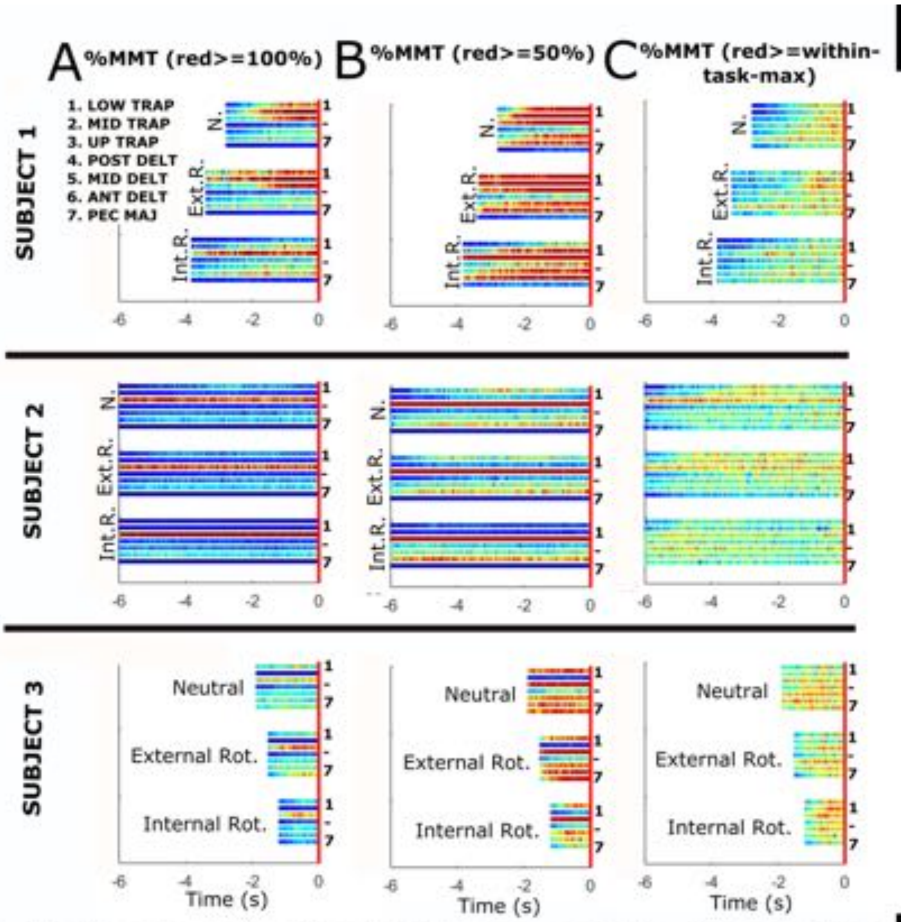

Fig. 2: Muscle activation heatmaps used during scaption tasks with varied shoulder internal/external rotation; shown such that high muscle activation is displayed in red and low activation in blue with different color-scale normalizations (A-C).

Figure 2

#5911

In Vivo Measurement of Distance Between Scapular Neck and Polyethylene Insert During Active External Rotation in Shoulders With Grammont Type Reverse Prosthesis

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[Background] Scapular notching is a complication after reverse shoulder arthroplasty with a high incidence up to 100%. Its clinical relevance remains uncertain; however, some studies have reported that scapular notching is associated with an inferior clinical outcome. There have been no published articles that studied positional relationship between the scapular neck and polyethylene insert in vivo. The purpose of this study was to measure the distance between the scapular neck and polyethylene insert in shoulders with Grammont type reverse shoulder arthroplasty during active external rotation at the side.

[Methods] Eighteen shoulders with Grammont type prosthesis (Aequalis Reverse, Tornier) were enrolled in this study. There were 13 males and 5 female, and the mean age at surgery was 74 years (range, 63-91). All shoulders used a glenosphere with 36mm diameter, and retroversion of the humeral implant was 10°in 4 shoulders, 15°in 3 shoulders, and 20°in 11 shoulders. Fluoroscopic images were recorded during active external rotation at the side from maximum internal to external rotation at the mean of 14 months (range, 7-24) after surgery. The patients also underwent CT scans, and three-dimensional glenosphere models with screws and scapula neck models were created from CT images. CT-derived models of the glenosphere and computer-aided design humeral implant models were matched with the silhouette of the implants in the fluoroscopic images using model-image registration techniques (Figure 1). Based on the calculated kinematics of the implants, the closest distance between the scapular neck and polyethylene insert was computed using the scapular model and computer-aided design insert models (Figure 2). The distance was computed at each 5° increment of glenohumeral internal/external rotation, and the data from 20°internal rotation to 40°external rotation were used for analyses. One-way repeated-measures analysis of variance was used to examine the change of the distance during the activity, and the level of significance was set at $P < 0.05$.

[Results] The mean glenohumeral abduction during the activity was 17°-22°. The mean distance between the neck and insert was approximately 1mm throughout the activity (Figure 3). The distance tended to become smaller with the arm externally rotated, but the change was not significant.

[Discussion] The reported incidence of scapular notching after Grammont type reverse shoulder arthroplasty is generally higher than the newer design prosthesis with the lateralized center of rotation. This may be associated with the design of the prosthesis, and the results of this study that the distance between the neck and insert was approximately 1mm throughout active external rotation at the side will support the high incidence of notching. We may need to analyze the distance with the newer design reverse shoulder prosthesis to prove the architectural advantage of the newer systems.

[Conclusion] The distance between the scapular neck and polyethylene insert was approximately 1mm throughout active external rotation activity in shoulders with Grammont type prosthesis.

Figures

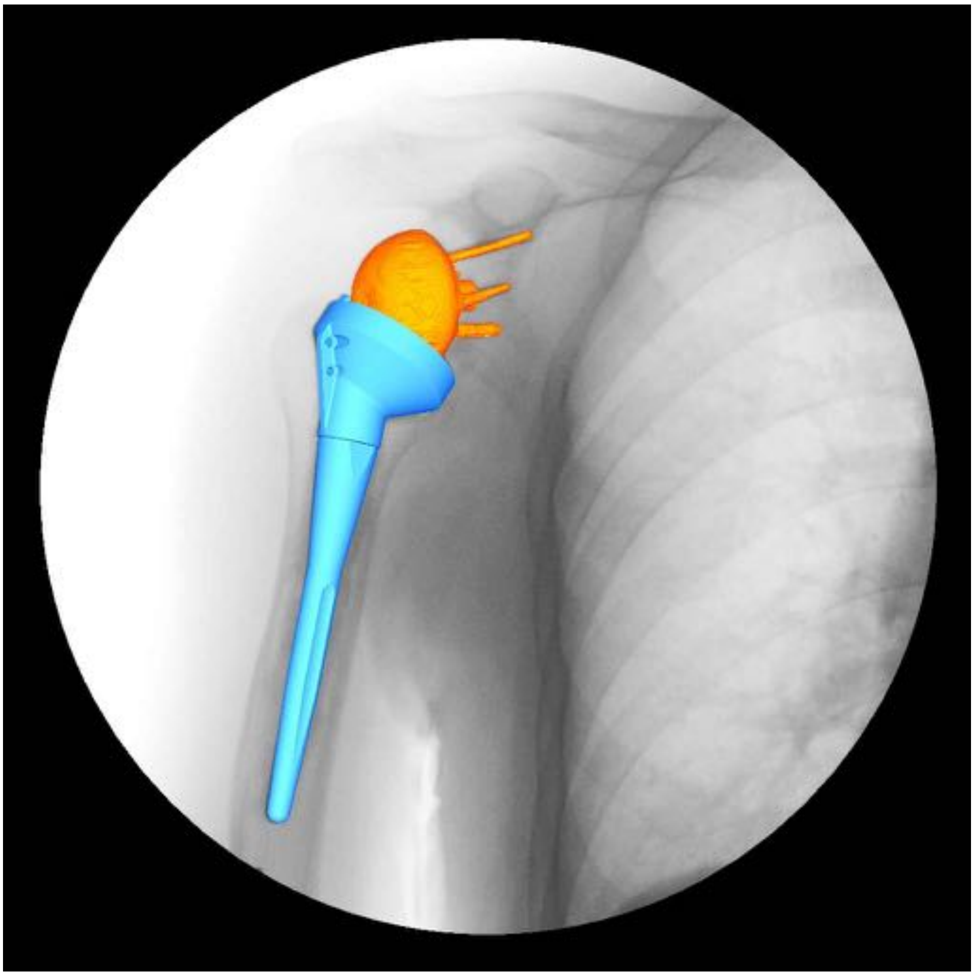

Figure 1

Figure 2

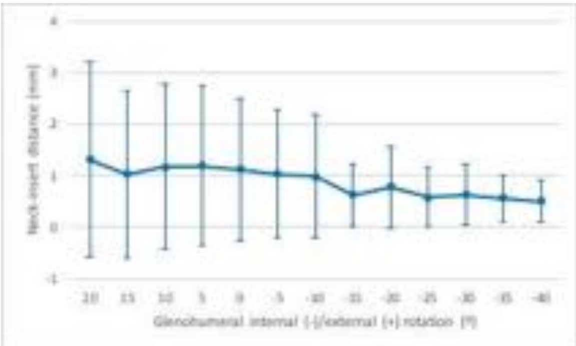

Figure 3

Inter-Surgeon Variability in Using 3D Planning Software for Anatomic Total Shoulder Arthroplasty: an Analysis of 360 Cases

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INTRODUCTION:

Preoperative planning software for anatomic total shoulder arthroplasty (ATSA) allows surgeons to virtually perform a reconstruction based off 3D models generated from CT scans of the glenohumeral joint. The purpose of this study was to examine the distribution of chosen glenoid implant as a function of glenoid wear severity, and to evaluate the inter-surgeon variability of optimal glenoid component placement in ATSA.

METHODS:

CT scans from 45 patients with glenohumeral arthritis were planned by 8 fellowship trained shoulder arthroplasty specialists using a 3D preoperative planning software, planning each case for optimal implant selection and placement. The software provided three implant types: a standard non-augmented glenoid component, and an 8° and 16° posterior augment wedge glenoid component. The software interface allowed the surgeons to control version, inclination, rotation, depth, anterior-posterior and superior-inferior position of the glenoid components in 1mm and 1° increments, which were recorded and compared for final implant position in each case.

RESULTS:

Five cases were excluded due to extreme glenoid wear. Average version, inclination, and millimeters of bone removed for each case along with standard deviations and implant selection are detailed in figure 1. For resultant implant version, a bimodal distribution was observed with a local maxima occurring at 0 degrees, and a bell-shaped distribution at -5° of version [Fig 2]. Upon individual surgeon analysis, it was revealed that certain surgeons had a preference to correct to 0 degrees, whereas others were more accepting of residual version. Shoulders ranged in native version from 0° to -27° with an average of -11°, indicating a high frequency of posterior glenoid wear. Figure 3 demonstrates the frequency of different implants used for each degree of version, showing that standard implants were never used when version was > -11°. Conversely, 16° augmented glenoids were never used when the version was < -9°. Based on this distribution, version was divided into 3 ranges: ≤ -6°, -7 to -14°, and≥ -15°. Standard glenoids were used 79% of the time when the version was ≤-6°. 8° augmented glenoids were used 80% of the time when the version was between -7° and -14°, and 75% of the time when the version was ≥ -15°. In the latter case, 16° augments were used in the other 25%. For inclination in ATSA, the same trends of a bimodal distribution seen for version were less pronounced. A local maxima of plans were focused around zero degrees, with some surgeons being more accepting of superior inclination in ATSA.

CONCLUSION:

While there was limited consensus on the optimal reconstruction in any one case, there appear to be thresholds of retroversion that favor the use of augmented glenoid components based on frequency of selection. Our data suggests when retroversion exceeds -7°, some degree of augmentation is helpful in achieving the goals of version correction while limiting bone loss through corrective reaming. Longer term clinical outcomes on specific implant positions will help to define true optimal implant placement.

Figures

Non-Augment (n=127, 36%)	-1.9	3.4	3.3	3.5	3.7	1.1
8° Posterior Augment (n=191, 54%)	-3.2	3.5	2.0	3.9	4.2	1.4
16° Posterior Augment (n=34, 10%)	-3.6	3.4	3.9	3.8	4.1	1.4

Figure 1

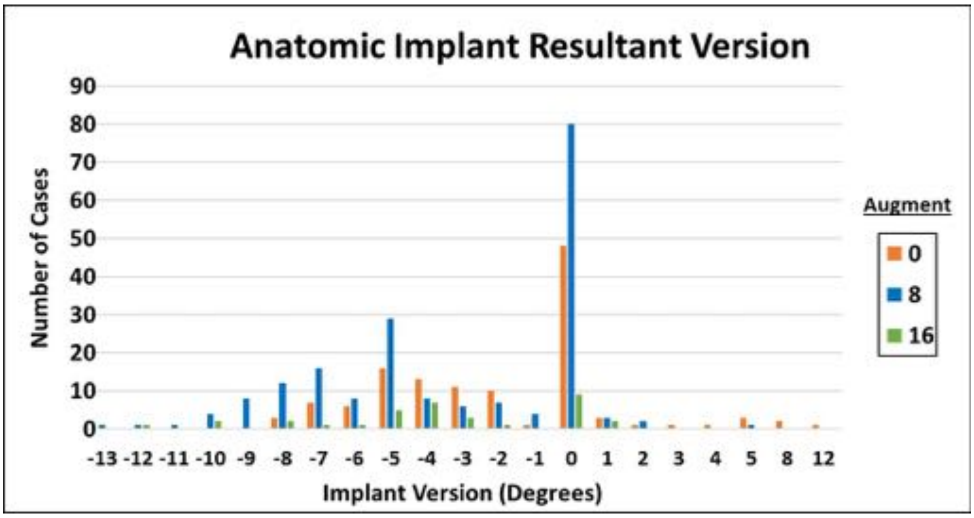

Figure 2

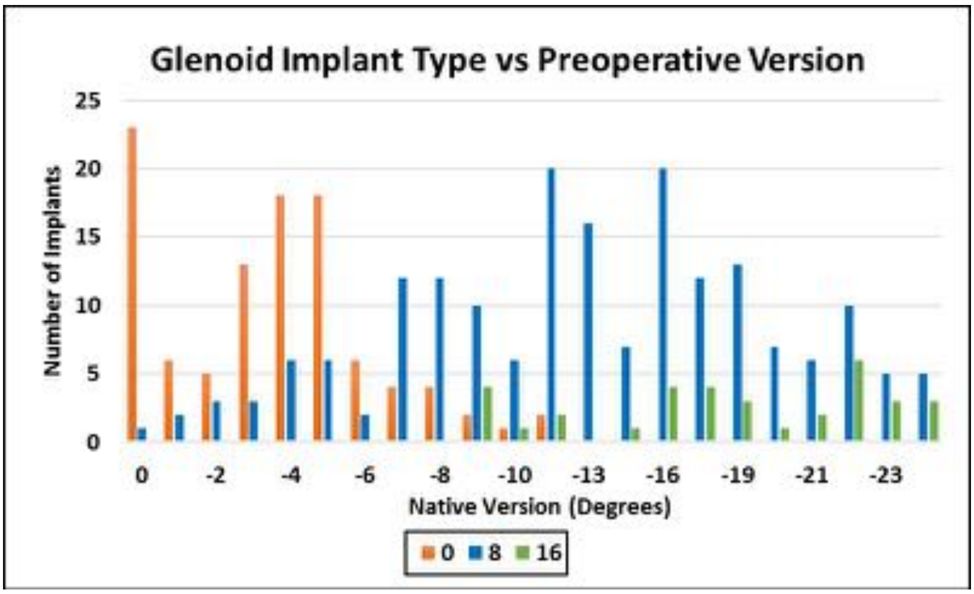

Figure 3

#6041

Does Preoperative Planning Simulation Software Aid Implant Positioning in TSA?

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INTRODUCTION

Total shoulder arthroplasty (TSA) is technically demanding and can be associated with failures due to implant loosening, especially in the presence of posterior glenoid bone loss. Novel preoperative planning has been used to try and improve implant positioning, however, there is little evidence on the effectiveness of these methods. Our goal was to assess the reliability and accuracy of three different preoperative planning software systems.

METHODS

We created 69 preoperative plans for TSA using CT studies with three preoperative planning systems: independent preoperative plan software (IPPS) and two automated manufacturer preoperative software systems (AMPS I and II). Preoperative glenoid version and inclination, implant version and inclination, as well as implant size were collected from each planning system for TSA and intraoperative implant records. Reliability and correlations between IPPS and each automated software were analyzed. Accuracy of implant size prediction obtained from IPPS and AMPS II to the actual implants used were compared. Paired-sample T tests and one-way ANOVA (Analysis of Variance) to compare the average head diameters and height measurements and Pearson's correlation coefficients (*r* values) were used to measure the strength of the correlations among the measurements performed by each software.

RESULTS

No significant differences were seen for glenoid version between the three preoperative simulation systems (IPPS: -12°; AMPS I: -11°; AMPS II: -11°; p=0.467) or implant version (IPPS: -6°; AMPS I: -6°; AMPS II: -5°; p=0.777). However, there were significant differences in glenoid inclination between IPPS (6°) and AMPS I (9°) (p=0.039) and implant inclination IPPS (3°) and AMPS II (6°) (p=0.001). Strong positive correlation was seen between IPPS and AMPS I measurements for glenoid version (r = 0.8) and implant version (r=0.7). For accuracy of simulation predicted humeral implant diameter, IPPS and AMPS II showed a perfect match in 36% and 56% of cases, respectively, while a matching rate within one size increased accuracy for IPPS to 72% and 79% for AMPS II.

DISCUSSION

Our resultsâ€¯support the use of either independent or commercially available preoperative simulation software to reliably and accurately guide intraoperative implant selection. â€¯Notwithstanding, some manufacturer's software (AMPS II) provideâ€¯more critical data, enhancingâ€¯precision in implant placement and correction of pathologic bone loss.â€¯

#6053

Accuracy of Preoperative Templating in Shoulder Arthroplasty

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INTRODUCTION

As the number of shoulder arthroplasties (SA) performed annually increases, orthopaedic surgeons have turned their attention to the longevity of implants and improving long-term functional outcomes for patients. However, this procedure can be technically challenging, especially for less experienced surgeons, and therefore new preoperative templating tools have been developed in order to guide shoulder surgeons in implant selection based on patient-specific CT scans. However, software precision is required to achieve shoulder surgeon’s goals. Therefore, we hypothesized that if the preoperative plan matched within one size up or down for implant selection, then this tool is accurate.

METHODS

This retrospective study included 24 patients with shoulder CT scans and preoperative templating plans using Tornier Blueprint™ 3D Planning software. All patients underwent shoulder arthroplasty by single fellowship trained surgeon. Accuracy was assessed by comparing software-predicted implant sizes with the actual implant sizes used intraoperatively. The components recorded and compared were baseplate and glenosphere diameter, and humeral stem size for RSA, and glenoid size and radius, and, humeral head diameter and thickness for TSA. Accuracy was assessed based on a perfect match and a match within one size larger or smaller.

RESULTS

Our results included preoperative plans and intraoperative implant selection for 14 RSA and 10 TSA procedures. For RSA, baseplate and glenosphere diameter perfectly matched in 78.5% of the cases and 100% within one size. Humeral stem size matched perfectly in 37.5% of the cases, but 100% of cases within one size variation. For TSA, glenoid implant backside curvature and implant size had 60% and 70% perfect accuracy, respectively, and a 100% accuracy within one size. Humeral head diameter and thickness had a similar match rate of 60% and 50%, respectively, and a 100% match rate within one size variation.

CONCLUSION

Overall, preoperative software implant predictions within one size of actual components for either RSA or TSA demonstrated a 100% accuracy rate. This high level of accuracy may improve operating room workflow and surgeon efficiency, which may ultimately translate to improved postoperative outcomes.

#5945

Clinical and Radiologic Results According to the Prosthesis Design and Placement in Reverse Total Shoulder Arthroplasty

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Introduction: Neck shaft angle (NSA), center of rotation (COR), glenoid inclination (GI) and inferior overhanging (IO) of prosthesis were reported in many studies as the important factors that affected on prognosis in reverse shoulder arthroplasty (RSA). This study aimed to assess the effect of multiple factors, including NSA, COR, GI and IO on the clinical and radiological prognosis according to the design of prosthesis and placement in RSA, and to suggest the guideline for selection of implant considering pros and cons of each implant.

Materials & Methods: This study included 141 shoulders underwent the RSA surgery at least 1-year follow-up. Average period of follow-up was 31.2 months. Four different types of the prosthesis were used in RSA. Pre- and post-operative active range of motion, visual analog scale pain score, American Shoulder and Elbow Surgeons score and Constant score were evaluated for the clinical outcomes. Scapular notching, component loosening, peri-prosthetic fracture, and acromial fracture were checked for assessment of the radiologic outcomes.

Results: The prosthesis of NSA of 155°, 145° and 135° were used in 71 cases(50.4%), 16(11.4) and 54(38.3), respectively. Each prosthesis of medialization and lateralization of COR were 29(20.1) and 112(79.9). The prosthesis of lateralization of glenoid and humerus were 96(68.1) and 16(11.4). Average GI and IO were 7.1° and 3.2mm. Scapular notching were 31 cases(22.0%). In prosthesis with high NSA, scapular notching was significantly increased($P<.0001$). The prosthesis with lateralization of COR showed significantly decreased scapular notching($P=.0483$). All clinical results, except for external rotation and internal rotation, were significantly improved postoperatively. There were a few differences in the clinical outcomes according to the notching, NSA, COR, and prosthesis. There was significant difference according to scapular notching between the glenoidal and humeral lateralization groups($P=.0392$). However, the clinical outcome was not different.

Conclusion: There were differences in the clinical results and the scapular notching, according to the design of prosthesis, NSA, and COR. High NSA and medialization of COR of prosthesis were negative factors for scapular notching in mid-term follow-up of RSA. For selecting implants, authors suggest that glenoidal lateralization and/or humeral lateralization with lower NSA design.

#6165

Clinical Results of Kudo Total Elbow Arthroplasty for Patients With Rheumatoid Arthritis

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Aims:

Kudo elbow is the most balanced surface-replacement elbow prosthesis in its design and intrinsic stability against rotaional torque, and yields one of the best results in treating patients with rheumatoid arthritis. However, not all is known how the techniques, approaches, degree of pre-operative stability, implant material and implant placement affect longevity of surface-replacing total elbow arthroplasty. We have investigated on the outcomes of rheumatoid arthritis patients treated with Kudo elbow arthroplasty.

Materials and methods:

We reviewed 60 patients with rheumatoid arthritis patients who underwent Kudo elbow arthroplasty at our institution and were followed up for more than two years. The material of the ulnar component was metal back in all except two cases. Mean post-operative follow-up period was 10 years.

Results:

Mean flexion improved from 112 degrees pre-operatively to 130 degrees post-operatively, and mean extension improved from -44 degrees to -30 degrees. Japanese Orthopaedic Association score out of 100 was improved from 46 points to 88 points. Humeral components were fixed cementlessly in all but two cases, and spot welds were observed at 5 post-operative month on average. Loosening was seen in one case with osteoporosis and a stove-pipe canal and another case with a severely stiff elbow, but neither had required revision surgery. As for the ulnar side, three cases underwent revision surgery, one due to polyethylene breakage after a fall and the other two due to wear and loosening. Two other cases had wear at the coronoid process. The 10-year survival rate with revision surgery as the endpoint was 90 percent.

Conclusion:

Kudo elbow arthroplasty provided good long-term results for rheumatoid arthritis patients, regardless of component placement methods and materials. However, some cases with more than 10 years of follow up develop wear of the ulnar polyethylene which may lead to loosening, hence future improvements in thickness and material of the polyethylene is essential.

#5740

Retrieval Analysis of Thirty Explanted NeuFlex Metacarpophalangeal Joint Prostheses

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Objective

We explanted NeuFlex metacarpophalangeal (MP) joint prostheses to identify common features, such as position of fracture, and thus better understand the reasons for implant failure.

Methods

Explanted NeuFlex MP joint prostheses were retrieved as part of an-ongoing implant retrieval programme. Following revision MP joint surgery the implants were cleaned and sent for assessment. Ethical advice was sought but not required. The explants were photographed. The position of fracture, if any, was noted. Patient demographics were recorded.

Results

Thirty NeuFlex MP explants were available. Seven (23%) were not fractured. Eleven explants (37%) had fractured at the hinge; nine (30%) had fractured at the junction of the distal stem and hinge; and three (10%) had fractured at both the hinge and distal stem. The different fractures sites are shown in figure 1. NeuFlex MP joint explants ranged in size from 0 to 40. Smaller sizes were retrieved from smaller fingers; larger implants came from the middle and index fingers. The age at revision ranged from 43 to 81 (median 58) years. Time in vivo ranged from 6 to 120 (median 58.5) months. All but two implants were obtained from rheumatoid joints, the remainder had osteoarthritis. Discolouration of some explants had occurred (figure 2); other explants appeared to show no colour change.

Conclusions

This is the first report of the position of fracture of NeuFlex explants. It is also the largest report of silicone arthroplasty explants. The majority (77%) had fractured. Nine (30%) NeuFlex explants had fractured at the junction of the distal stem and hinge; the typical position seen with Swanson and Sutter/Avanta MP joint explants. Eleven (37%) fractured across the hinge; this has not previously been reported although has been seen in in vitro testing. The hinge is thinner than the hinge-stem junction so may be at risk of more rapid failure, however the median time in vivo for hinge fractures was 63 months as opposed to 54 months for fractures at the distal stem. Intriguingly, 3 (10%) NeuFlex explants suffered fractures both at the hinge and at the junction of the distal stem and hinge which has also never been reported previously. Fracture at the junction of the distal stem and hinge shows the importance of subluxing forces in rheumatoid MP joints and therefore suggests these need to be mitigated as much as possible. Fracture across the hinge could indicate this as a position which could be increased in thickness, to increase the time taken to fracture, although there may be a concomitant increase in stiffness of the implant. With improved designs, patients might suffer fewer or later failures. The latest Norwegian Arthroplasty Registry report shows that revision MP joint arthroplasties accounted for 42% of all MP joint replacement operations in 2015. Therefore this is an important area where opportunities exist to reduce revision rates.

Figures

Figure 1

Figure 2

#6148

The Preventive Role Against Adjacent Segment Disease of Interspinous Process Device After a Rigid Instrumented Level in Lumbar Degenertive Disease.

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INTRODUCTION

The elimination of motion and disc stress produced by spinal fusion may have potential consequences beyond the index level overloading the spinal motion segments and leading to the appearance of degenerative changes. So the “topping-off” technique is a new concept instructing dynamic fixation such as interspinous process device (IPD) for the purpose of avoiding adjacent segment disease (ASD) proximal to the fusion construct.

MATERIALS AND METHODS

The study simulated spinal fusion in L4-L5, fusion combined DIAM in L3-L4. The ROM and maximum von Miss stresses were analyzed in flexion, extension, lateral bending, and torsion in response to hybrid method, compared to intact modeland fusion model.

RESULTS

The investigation revealed that decreased ROM, intradiscal stress in implanted level but a considerable increase in stresses at more upper level (L2-L3) during flexion and extension in hybrid model, comparing with the fusion model.

CONCLUSIONS

The raise of intradiscal pressure at the adjacent segment to a rigid fusion segment can be reduced when the rigid construct is augmented with an interspinous process device. However, the burden of stress over total spinal segments was still the same, the stress and ROM were just shift to supraadjacent levels.

#5636

The Precision of Low Field MRI to Measure Prosthetic Migration; a Cadaver Study.

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Introduction:

Roentgen stereophotogrammetric analysis (RSA) is currently the gold standard to measure early prosthetic migration which can predict aseptic loosening. However, RSA has some limitations such as the need for perioperative placed markers and exposure to X-radiation during follow up. Therefore, this study evaluates if low field MRI could be an alternative for RSA. Low field MRI was chosen because it is less hampered by metal artifacts of the prosthesis than high field MRI.

Method:

3D models of both the tibial component of a total knee prosthesis (Genesis II, Smith and Nephew) and the porcine tibia were made. The tibial component was implanted in the tibial bone. Consequently, 17 acquisitions with the low field MRI scanner (Esaote G-scan 0.25T) in transverse direction with a 2D PD weighted metal artifact reducing sequence PD-XMAR (TE/TR 10/1020ms, slice thickness 3mm, FOV 180x180x120 mm^3, matrix size 224x224) were made. The first five acquisitions were made without repositioning the cadaver, the second twelve after slightly repositioning the cadaver within limits that are expected to be encountered in a clinical setting. Hence, in these 17 acquisitions no prosthetic-bone motions were induced. The scans were segmented and registered with Mimics. Virtual translation and rotation of the prosthesis with respect to the bone between two scans were calculated using a Procrustes algorithm. The first five scans without repositioning were used to calculate the measurement error, the following twelve to calculate the precision of low field MRI to measure prosthetic migration. Results were expressed as the maximum total point motion, mean error and 95% CI and expressed in boxplots.

Results:

An overview of the results is provided in figure I. The error of the method to measure the prosthetic position without repositioning has a mean translation between 0.09 and 0.22mm with a 95%CI between 0.30 and 0.46mm. The mean rotation was between 0.02° and 0.11° with a 95%CI between 0.18° and 0.32° with a MTPM of 0.45mm.

The precision of low field MRI to measure migration with repositioning has a mean translation between 0.02 and 0.12mm with a 95%CI between 1.16mm and 1.86mm. The mean rotation was between 0.01° and 0.15° with a 95%CI between 1.78° and 3.26° with a MTPM of 2.35mm. The overall registration error was largest in the distal-proximal direction.

Discussion:

At the moment the low field MRI technique is not as accurate as this gold standard RSA. The accuracy of RSA varies between 0.05 and 0.5 mm for translation and 0.15â° to 1.15â° for rotation (95% confidence intervals). However, results are comparable with markerless RSA studies. The largest measurement error was found in the distal-proximal direction, which can be explained by the through-plane resolution of 3 mm, which is larger than the in-plane resolution of 0.8x0.8 mm². Future research should focus on improving resolution in the distal-proximal direction which would improve the precision. Moreover, an actual migration study should be performed to proof the true value of this low field MRI base markerless and X-radiation free alternative to measure prosthetic migration.

Figures

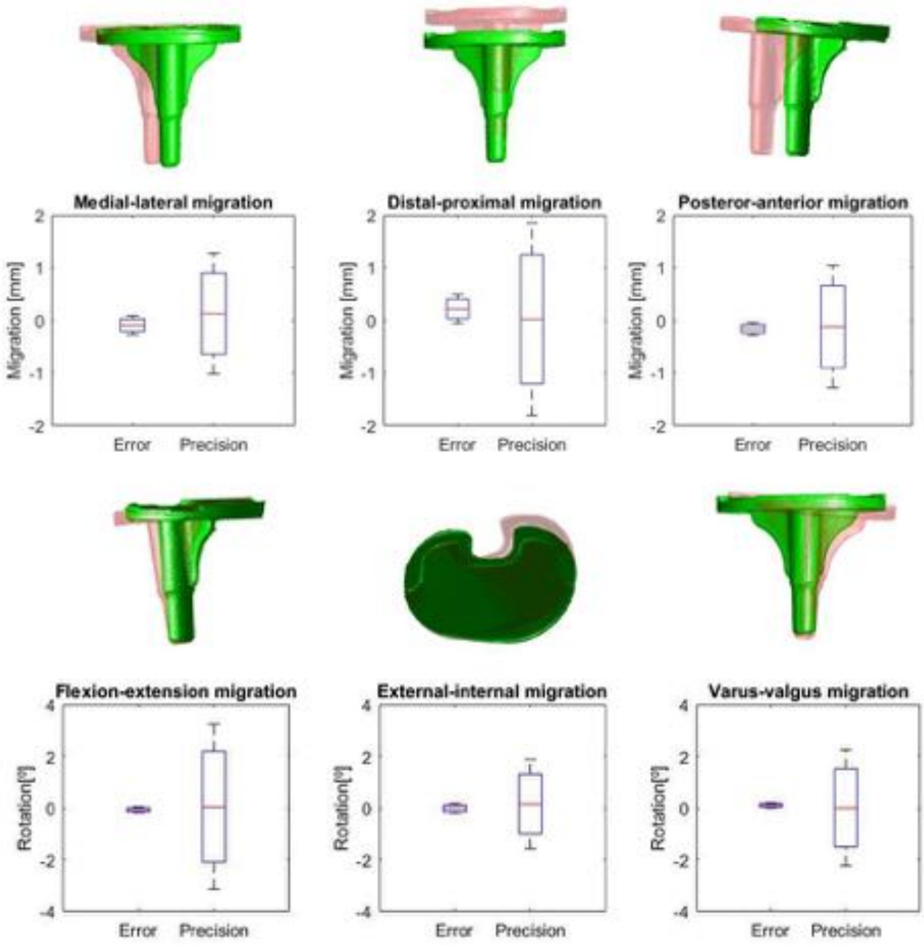

Figure 1: Boxplots for the six degrees of freedom, for translation and for rotation for the measurement error and the precision of low field MRI for measuring prosthetic migration.

Figure 1

#6076

Joint Surface Contact Estimation Using 3D Scan and Navigation System: Preliminary Results

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Background:

Joint motion is defined by bone contact between their surfaces. To restore correct functionality, it is needed to be able to assess contact surfaces between bones during joint motion. Contact surfaces information is crucial for implant positioning, soft tissues balancing and joint surface modification. Actually, the joint surface is obtained with pre-op medical imaging registered with several point measured with the digitizer from navigation system. This time-consuming task, also could not allow to obtain the full surface once it have been altered during the surgery.

The purpose of this study is to assess the possibility to estimate the joint contact surfaces with a 3D scanner and tracking data from a navigation system.

Material and Method:

A knee joint composed of femur and tibia sawbones have been equipped with appropriate markers. The femur was fixed and the tibia mobile. The knee has been flexed and extended from 0 to 35 degrees. The surface has been scanned at 0.1 mm resolution 3D scanner (Artec spider). The motion of each joint has been measured with both high-end (Optitrack, 18 cameras) and low-cost (Clarion Micron) navigation systems. The tibia position recorded with the low-cost motion capture was compared with the reference motion from the high-end motion capture. The tibia and femur bone were considered in contact when the distance between their respective surface was lower than 1mm.

Results:

The low-cost motion capture absolute position error was 1.79±0.29 mm. The rotation error was 1.10±0.16°, 1.39±0.65°, -0.20±0.26° respectively for the flexion/extension, varus/valgus and internal/external rotation. The pattern of the contact surface between the high-end and low-cost motion capture described equivalent patterns (Fig.1).

Discussion:

These preliminary results show that the tracking data from the low-cost and the high-end tracking system are comparable but the tracking error impact slightly the contact surface obtained with the low-cost system. However, future works will focus on the improvement of the tracking quality with filtering methods, the validation of the contact surfaces computed and its computation to achieve real-time display.

Acknowledgement:

This project has been supported by St Georges Charity and ORUK foundation.

Figures

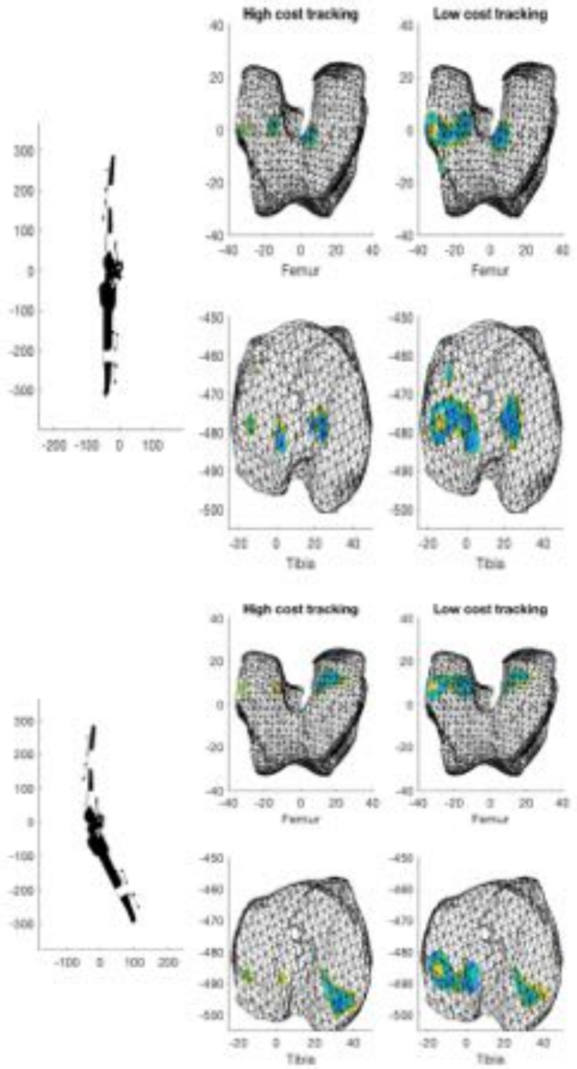

Fig1: Contact surface patterns obtained with a low-cost and a high-end motion-capture system at different knee flexion angles (0°,35°).

Figure 1

#5682

Evaluation of Tibial Component Rotation in Painful Total Knee Arthroplasties by MRI Enhanced With Metal Artifact Reduction Technique.

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Introduction: Tibial component malrotation is one of the commonest causes of pain and stiffness following total knee arthroplasties, however, the assessment of tibial component malrotation on imaging is not a clear-cut.

Aim: The objective of this study was to assess tibial component rotation in cases with pain following total knee replacement using MRI with metal artifact reduction technique.

Methods: In 35 consecutive patients presented to our clinic between January 2016 and April 2017 with persistent unexplained moderate to severe pain for at least 6 months following total knee arthroplasties after exclusion of infection, MRI evaluation of tibial component rotation using O-MAR technique-(Metal Artifact Reduction for Orthopedic implants) to improve visualization of soft tissue and bone by reducing artifacts caused by metal implants- was done according to the technique of Berger et al.

Results: 25 cases showed internal rotation of tibial component, 5 cases showed neutral rotation, 5 cases showed external rotation with presence of abnormal intraarticular fibrous bands.

Conclusion: Two main conclusions are obtained from this study:

Firstly: Internal rotation of tibial component must be excluded in all cases of persistent pain following total knee replacement.

Secondly: Magnetic resonance imaging with the newly developed metal artifact reduction techniques is a very useful tool in evaluating cases of unexplained pain following total knee replacement.

#6152

A Guide to Diagnose Failed TKA; a Case Study Comparing Low-Field and High-Field MRI.

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Introduction:

Fifteen percent of the primary total knee arthroplasties (TKA) fails within 20 years. Among the main causes for revision surgery are instability and patellofemoral pain (Figure 1). Currently, the diagnostic pathway requires various diagnostic techniques to reveal the original cause for the failed knee prosthesis and is therefore time consuming and inefficient. Accordingly, there is a growing demand for a diagnostic tool that is able to simultaneously visualize soft tissue structures, bone and TKA. Magnetic resonance imaging (MRI) is capable of visualising all the structures in the knee although a trade-off needs to be made between metal artefact reducing capacities and image quality. Low-field MRI (0.25T) results in less metal artefacts and a lower image quality compared with high-field MRI (1.5T). The aim of this study is to develop a MRI imaging guide to image the problematic TKA and to evaluate this guide by comparing low-field and high-field MRI on a case study.

Method:

Based on literature and current differential diagnostic pathways a guide to diagnose patellofemoral pain, instability, malposition and signs of infection or fracture with MRI was developed. Therefore, methods as Insall Salvati, patellar tilt angle and visibility of fluid and soft tissues were chosen (Figure 1). Visibility was scored on a VAS scale from 0 to 100mm (0mm zero visibility, 100mm excellent visibility).

Subsequently, this guide is used to analyse MRI scans made of a volunteer (female, 61 years, right knee) with primary TKA (Biomet, Zimmer) in sagittal, coronal and transversal direction with a FSE PD metal artefact reducing (MAR) sequence (TE/TR 12/1030ms, slice thickness 4.0mm, FOV 260x260x120m^3, matrix size 224x216) on low field MRI (Esaote G-scan Brio, 0.25T) and with a FSE T_1-weighted high bandwidth MAR sequence (TE/TR 6/500ms, slice thickness 3.0mm, FOV 195x195x100m^3, matrix size 320x224) on high field MRI (Avanto 1.5T, Siemens).

Scans were analysed three times by one observer and the intra observer reliability was calculated with a two-way random effects model intra class correlation coefficient (ICC).

Results:

Due to less metal artefacts on the low-field MRI scans the angle, distant and ratio measurements were more consistent: Insall Salvati low-field 0.97-0.99, Insall Salvati high-field 1.05-1.12, patellar tilt angle low-field 2.1-2.8, patellar tilt angle high-field 2.4-7.6°.

Over all, the VAS scores are higher on the high-field MRI scans; VAS medial collateral ligament high-field 26-45, VAS medial collateral ligament low-field 24-34, VAS patellar tendon high-field 15-27, VAS patellar tendon low-field 2-7.

The ICC values of the VAS scores, angle measurements and ratio measurements were excellent, ICC > 0.9. The ICC values of the distance measurements were moderate, ICC > 0.6.

Conclusion:

MRI offers possibilities to simultaneously differentiate underlying causes of the failed knee prosthesis. The structures of interest were more clearly visible on the high-field MRI scans due to higher image contrast. The angle, distant and ratio measurements were more consistent on the low-field MRI scans due to less metal artefacts. Further research should focus on a larger group of patients with complaints after TKA to verify the analysis methods.

Figures

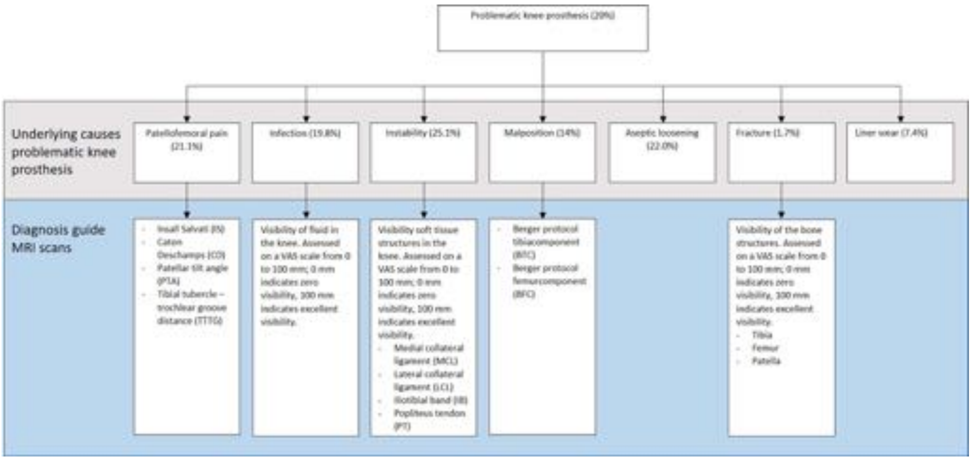

Figure 1

#5519

Magic Angle Directional Imaging (MADI) in a Partially Torn Canine ACL Provides Quantification of Ligament Health.

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Introduction: Cruciate retaining knee replacements are only implanted into patients with "healthy" ligaments. However, partial anterior cruciate ligament (ACL) tears are difficult to diagnose with conventional MRI. Variations of signal intensity within the ligament are suggestive of injury but it is not possible to confirm damage or assess the collagen alignment within the ligaments. The potential use of Magic Angle Directional Imaging (MADI) as a collagen contrast mechanism is not new, but has remained a challenge[1]. In theory, ligament tearing or joint degeneration would decrease tissue anisotropy and reduce the magic angle effect[2]. Spontaneous cruciate ligament rupture is relatively common in dogs. This study presents results from ten canine knees.

Methods: Ethical approval was obtained to collect knees from euthanized dogs requiring a postmortem (PM). A Siemens Verio 3T MRI scanner was used to scan a sphere containing the canine knees in 9 directions to the main magnetic field (B_0) with an isotropic 3D-T1-FLASH sequence. After imaging, the knees were dissected and photographed. The images were registered and aligned to compare signal intensity variations. Segmentation using a thresholding technique identified voxels containing collagen. For each collagen-rich voxel the orientation vector was computed using Szeverenyi and Bydder's method[3]. Each orientation vector reflects the net effect of all fibers comprised within a voxel. The assembly of all unit vectors represents the fiber orientation map and was visualised in ParaView[4] using streamlines (**Fig1**). The Alignment Index (AI) is defined as a ratio of the fraction of orientations within 20° (solid angle) centred in that direction to the same fraction in a random (flat) case[5]. By computing AI for a regular gridded orientation space we can visualise differences in AI on a hemisphere (**Fig2**). AI was normalised so that AI=0 indicates isotropic collagen alignment. Increasing AI values indicate increasingly aligned structures: AI=1 indicates that all collagen fibers are orientated within the cone of 20° centred at the selected direction.

Results: Dogs cranial cruciate ligament (CCL) is similar to human ACL (**Fig3A:** healthy CCL). It's composed of an anteriomedial (AM) bundle and a posteriolateral (PL) bundle. Two knees were damaged with partial CCL tears, the PL bundle was intact but the AM bundle was torn (**Fig3B**).

Paraview streamlines of the CCL for healthy and damaged knees are shown in **Fig1**. The healthy knee has continuous fiber tracts (**A**) with no ligament disruption. In (**B**) the AM bundle fibers (red) are discontinuous and the PL bundle fibers (blue, behind) are continuous as expected in a partially torn CCL.

The AI for healthy (**A**) and damaged (**B**) CCL is shown in **Fig2.** The damaged AM bundle has a more diffuse spread of less aligned fibers compared to the more concentrated and aligned PL fiber bundle.

Conclusion This study demonstrates the first visualisation of a CCL partial tear using MADI. Combined with AI, our scanning technique offers a tool to visualise and quantify changes in collagen fiber orientation. Thus, MRI can be used to improve the diagnosis and quantification of partial ligament tears in the knee.

Figures

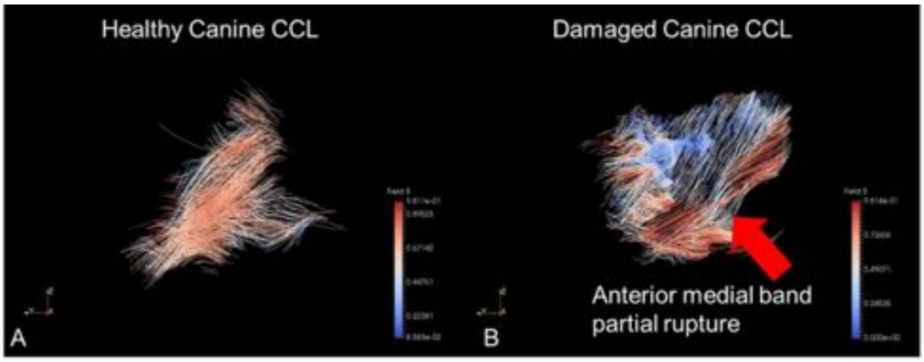

Fig1: The Paraview streamline tracts of CCL from a healthy (**A**) canine knee and a damaged (**B**) canine knee in a sagittal oblique plane. Note that the fibers of the AM band are discontinuous in (**B**) demonstrating a partially torn ligament. This is the same specimen photographed in **Fig3B**.

Figure 1

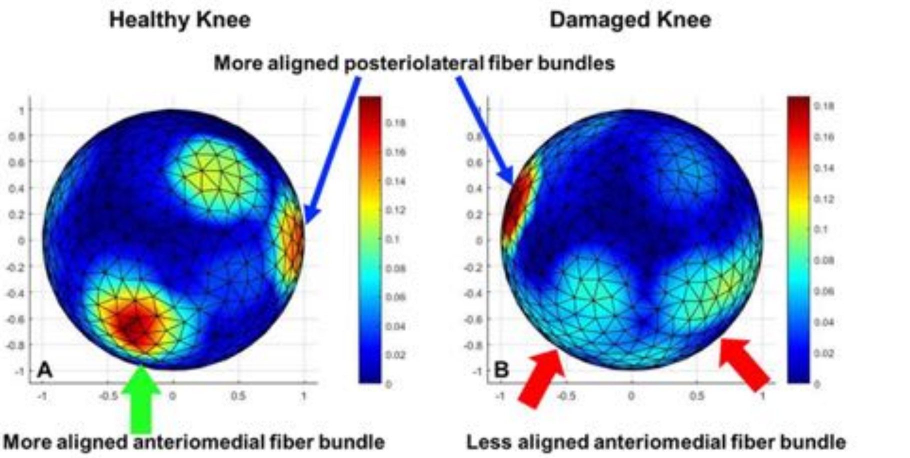

Fig2: The AI of a healthy (**A**) CCL compared to a damaged (**B**) CCL. In **A** the AM and PL fiber bundles are concentrated and more aligned compared to **B** where the PL fibers are aligned but the AM fibers are spread over the lower hemisphere indicating disorganisation due to the partial tear.

Figure 2

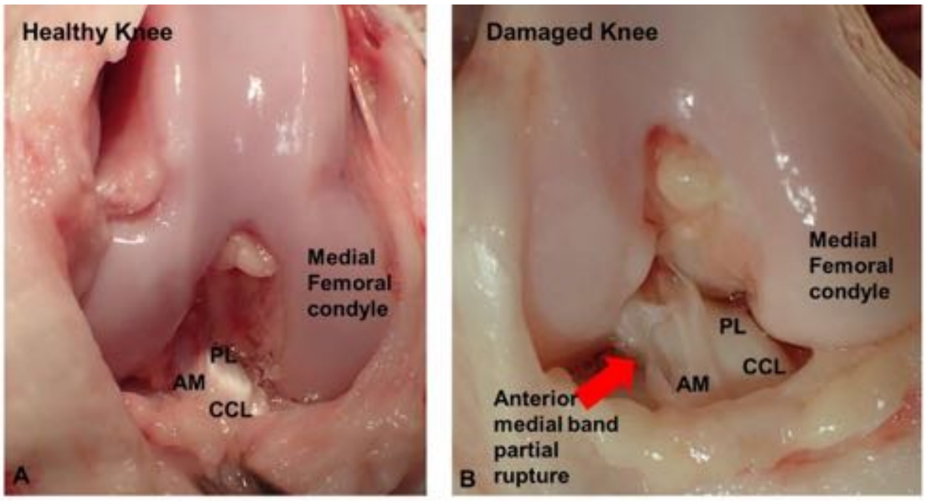

Fig3: Post mortem photographs of a healthy (**A**) and damaged (**B**) cranial cruciate ligament (CCL). In (**B**) the anteriomedial (AM) bundle (red arrow) is damaged and the posteriolateral (PL) bundles is intact which was diagnosed as a partial tear of the CCL.

Figure 3

Reproducibility of Pelvic Sagittal Inclination While Acquiring Radiographs in Supine and Standing Postures

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Introduction: Pelvic position on the sagittal plane is often quantified by measuring the pelvic sagittal inclination (PSI) angle, which is the angle between the anterior pelvic plane (APP) and the body line for the supine posture (Fig. 1a) and between the APP and the line perpendicular to the floor for the standing posture (Fig. 1b). Usually, PSI is preoperatively measured from a single radiograph to plan for hip surgery. However, the reproducibility of pelvic positioning has not been investigated, and thus, the validity of measuring the PSI from a single film/time-point is not understood. Herein, the reproducibility of a patient's pelvic positions in supine and standing postures was analyzed. The study hypothesis was that PSI is highly reproducible.

Materials and Methods: Thirty-four patients who underwent either a pelvic osteotomy or total hip arthroplasty were enrolled in this study. Preoperative radiographs in both supine and standing postures were acquired twice (1st X-ray and 2nd X-ray) within six months; preoperative CT images of the full pelvis were also acquired in a supine posture (preop-CT). To eliminate measurement variability, each PSI was automatically measured from radiographs and CT images through the use of CT segmentation and landmark localization followed by intensity-based 2D-3D registration. The absolute difference of PSI among each image was calculated and the intra-class correlation coefficient (ICC) in each posture was also analyzed.

Results: The median absolute differences of PSI in the supine posture were 1.3° between the 1st and 2nd X-rays, 1.2° between the 1st X-ray and preop-CT, and 1.3° between the 2nd X-ray and preop-CT. The median absolute difference of PSI in the standing posture was 1.5°. There were only a cumulative total of two cases (6%) which showed a difference of more than 5° among the three measurements in the supine position (one case between the 1st X-ray and the preop-CT, and another case between the 1st X-ray and the 2nd X-ray: Fig. 2a, 2b, Circle dots indicate each case and the cross marks indicate the case in which a difference of ≥5° was observed). For the standing position, only three cases (9%) showed a difference of more than 5° between 1st X-ray and the 2nd X-ray (Fig. 2c). The ICC was 0.965 (95% CI: 0.939-0.981) in supine and 0.977 (95% CI: 0.954-0.988) during standing.

Discussion and conclusions*:* The patient's pelvic positions in the supine and standing postures on the radiographic planes are highly reproducible during the pre-operative period, at least when obtained within 6 months. Therefore, we recommend that a single film be acquired to measure the PSI when surgery is anticipated within 6 months from acquisition of the first film.

Figures

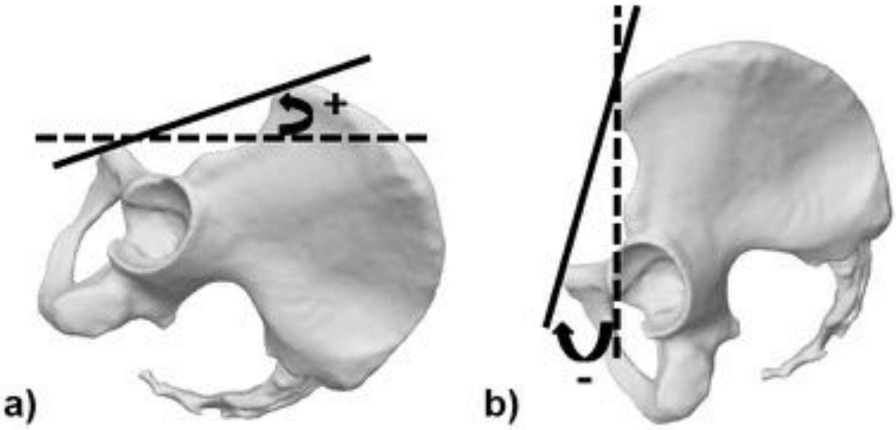

Figure 1

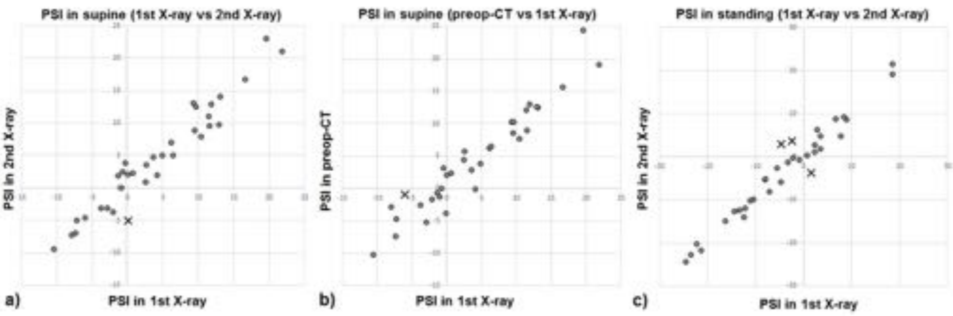

Figure 2

#5794

Accuracy of Different CT-Based Methods for Measuring Implant Placement Errors

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Introduction: The ability to place an implant accurately according to a preoperative plan is a primary goal of computer-assisted surgical systems for total hip and knee arthroplasties (TKA, THA). To assess whether the implants have been placed according to a preoperative plan based on CT scanning, one option is to perform a postoperative CT scan and to generate 3D models of the bones and implants so that differences in position and orientation between planned and postoperative 3D implant models can be determined in all six degree-of-freedom (6DoF). This comparison requires two steps, 1) a 3D-to-3D registration between the preoperative and postoperative 3D bone models to generate a common reference frame, and 2) a 3D-to-3D registration between the planned and postoperative 3D implant models to compute the 6DoF differences between planned and executed implant placements. Each of these two steps is affected by measurement errors that can ultimately affect the 6DoF differences in implant placement. Hence, the aim of this paper is to determine the measurement errors (6DoF) for 1) the 3D-to-3D registration of 3D bone models using each of six methods; 2) the 3D-to-3D registration of 3D implant models, 3) the overall procedure.

Methods: Eighteen lower limbs specimens free of degenerative joint disease were implanted with 3D-printed spherical fiducial markers and CT-scanned preoperatively. Twelve specimens were used to perform preoperative plan for THA (stem only) and six specimens were used to perform preoperative plan for TKA (femoral component only). Next, THA and TKA surgeries were performed using the TSolution One System (THINK Surgical Inc., Fremon CA) and CT scans were performed postoperatively. Six different methods were used to perform the 3D-to-3D registration between preoperative and postoperative 3D bone models (Figure 1), while laser scanning was used to assess the measurement errors in the 3D-to-3D registration of the 3D implant models (Figure 2).

Results: The least accurate method to register the 3D bone models was using separately the distal femur, the proximal femur, and the diaphysis only with RMSE within 2.2 mm and 0.4° (Figure 3). In all other cases, the errors were within 0.2 mm and 0.2°. The RMSE for the 3D-to-3D registration of the 3D implant models were within 0.8° and 0.3 mm. Overall, the combined RMSEs for 3D-to-3D registration of the 3D bone and implant models were within 1 mm and 0.5° using the distal or proximal femur with diaphysis and the full femur, and within 3 mm and 1° using the distal/proximal femur only.

Conclusion: The main findings of this study are 1) the regions of bone used for 3D-to-3D registration notably affect the accuracy of this measurement technique; 2) implant registration is the most significant source of error; 3) the overall errors are smallest when the proximal femur and/or distal femur with diaphysis is used for bone registration. In conclusion, only the methods that include the proximal or distal femur with diaphysis are likely to be appropriate for typical component placement error studies, as the measurement errors are sufficiently small.

Figures

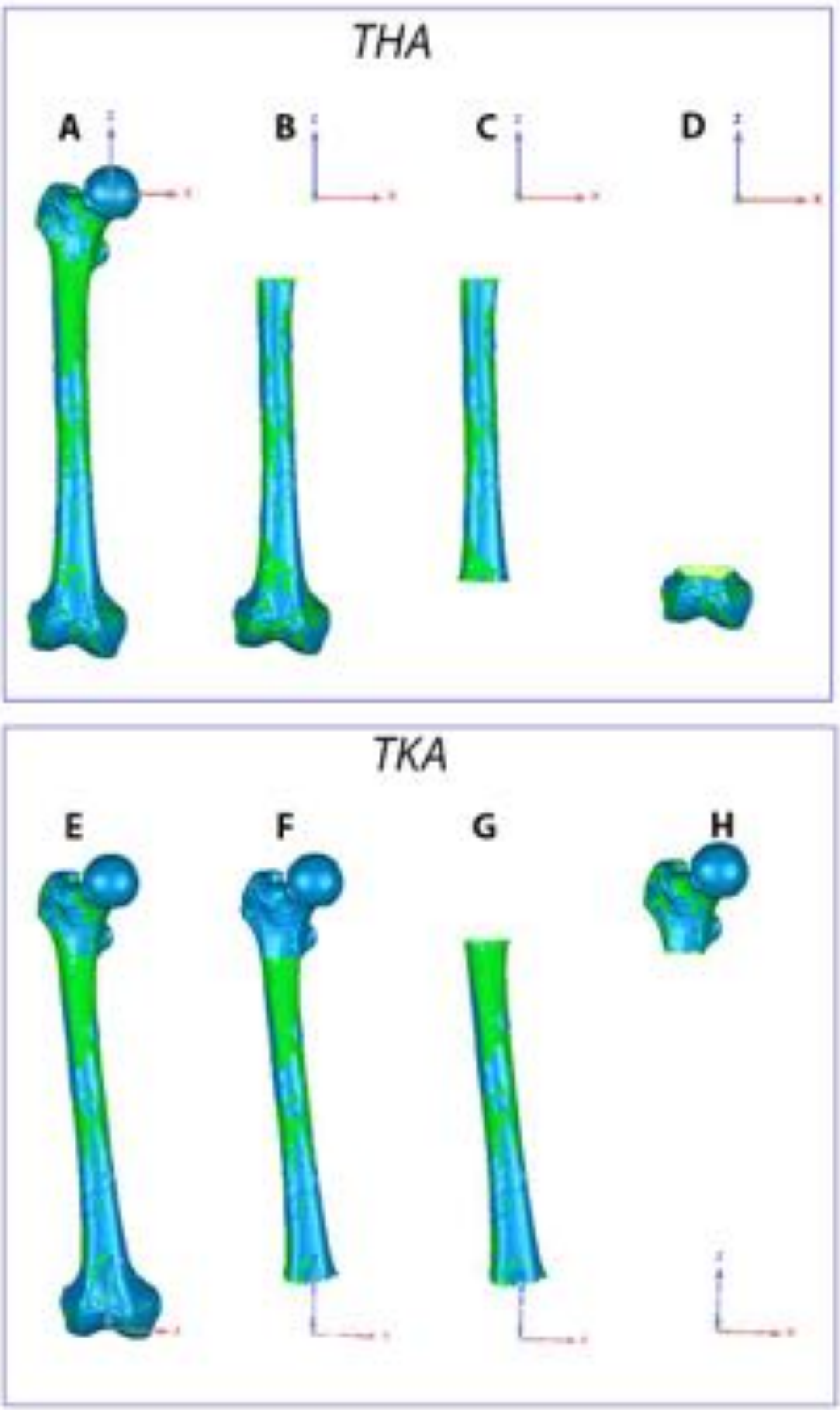

Figure 1. Description of the six different methods used to register the preoperative bone model with the postoperative bone model in the THA (A to D) and TKA (E to H) cases with different coordinate systems. Each method uses a different region of bone for the registration: 1) full femur (A-E), 2) diaphysis and distal femur (B), 3) diaphysis (C-G), 4) distal femur (D), 5) diaphysis and proximal femur (F), 6) proximal femur (H). In the THA cases, the proximal femur is not available in the postoperative bone model which justify why methods B-C-D do not include the proximal region. Equally, in the TKA cases, the distal femur is not available in the postoperative bone model which justify why methods F-G-H do not include the distal region. In both THA and TKA cases, the full femur was used as a best case scenario.

Figure 1

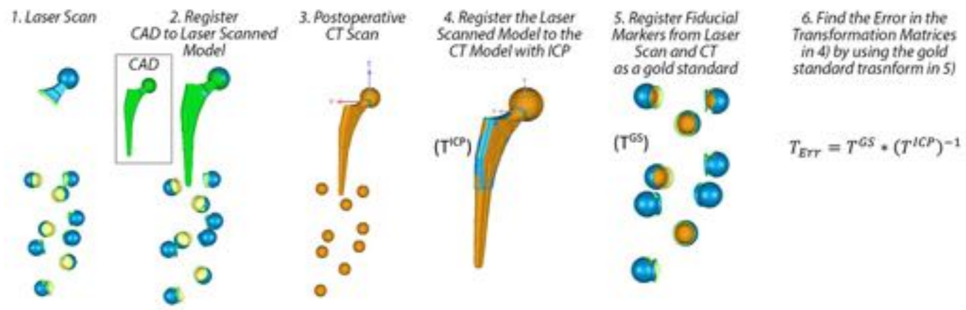

Figure 2

TKA	Full Femur - Ideal Case			Proximal Femur Only			Proximal Femur and Diaphysis			Diaphysis Only		
Translations (mm)	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**
Medial-Lateral	0	0.1	0.1	0.2	1.6	1.6	0	0.2	0.2	-0.5	0.1	0.5
Anterior-Posterior	-0.2	0.1	0.2	-0.6	0.9	1.1	-0.1	0.2	0.2	0	0.2	0.2
Proximal-Distal	0	0.1	0.1	-0.1	0.2	0.2	-0.1	0.2	0.2	0.2	0.6	0.6
Rotations (deg)												
Flexion-Extension	0	0	0.1	-0.1	0.1	0.2	0	0	0.1	0	0.1	0.1
Varus-Valgus	0	0	0	0	0.2	0.2	0	0	0	0	0	0
Internal-External Rotation	0	0.1	0.1	0	0.2	0.2	0.1	0.2	0.2	0	0.2	0.2

THA	Full Femur - Ideal Case			Distal Femur Only			Distal Femur and Metaphysis			Diaphysis Only		
Translations (mm)	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**	**Bias**	**Precision**	**RMSE**
Medial-Lateral	-0.1	0.1	0.2	-0.3	1.1	1.1	0.1	0.1	0.1	0.1	0.2	0.5
Anterior-Posterior	0.2	0.2	0.2	0.6	2.1	2.2	0.1	0.2	0.2	0.1	0.4	0.4
Proximal-Distal	0.0	0.1	0.1	0.1	0.3	0.3	0.0	0.2	0.2	0.1	1.1	1.1
Rotations (deg)												
Flexion-Extension	0.0	0.0	0.1	-0.1	0.3	0.4	0.0	0.0	0.0	0	0.2	0.2
Varus-Valgus	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0	0	0
Internal-External Rotation	0.0	0.1	0.1	-0.1	0.2	0.2	0.0	0.1	0.1	-0.2	0.8	0.8

Figure 3. Results from the 3D-to-3D bone model registration for THA and TKA.

Figure 3

Total Knee Kinematics Determine Patient Satisfaction After TKA

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Background: Kinematic patterns in total knee arthroplasty (TKA) can vary considerably from the native knee. No study has shown a relation between a given kinematic pattern and patient satisfaction yet.

Questions: The purpose of this study was to test whether the kinematical pattern, and more specifically the anteroposterior translation during (1) open kinetic chain flexion-extension, (2) closed kinetic chain chair rising and (3) squatting, is related to the level of patient satisfaction after TKA.

Methods: Thirty TKA patients were tested using single plane fluoroscopy. Tibiofemoral kinematics were analyzed for 3 activities of daily living (open chain flexion-extension (FE) and closed chain chair rising (CH) and squatting(SQ)). A two-step cluster analysis was performed which resulted in two clusters of patients based on the KOOS and KSS questionnaires. Cluster 1 (CL1) contained patients with good PROMs, cluster 2 (CL2) contained patients with poorer PROMs. Tibiofemoral kinematics were compared between and within both clusters.

Results: Significant worse PROMs were found in cluster 2 for all KOOS and KSS subscores ($P<0.001$).

<u>Open chain movement</u>: Concerning the open chain flexion extension no significant difference was found between the two clusters.

<u>Closed chain movements:</u> On the medial side, an initial anterior translation (femur relative to tibia) was found in cluster 1 during early flexion but in cluster 2 this translation was steeper and ran more anteriorly. In mid-flexion a stable medial compartment was found in cluster 1 where cluster 2 started moving posteriorly already. In deep flexion a posterior translation was evaluated in both clusters

Concerning the lateral side, a small initial anterior translation in early flexion was found followed by a posterior translation in mid flexion which continued in deep flexion Cluster 1 moved significantly more posterior in deep flexion.

Conclusion:

This is one of the first studies to evaluate the influence of total knee kinematics on patient reported outcomes. We found that patients with poorer PROMs experience (1) a more pronounced paradoxical anterior motion on the medial side followed by (2) a less stable medial compartment in mid flexion and (3) less posterior translation in deep flexion on the lateral side.

<u>Figures</u>

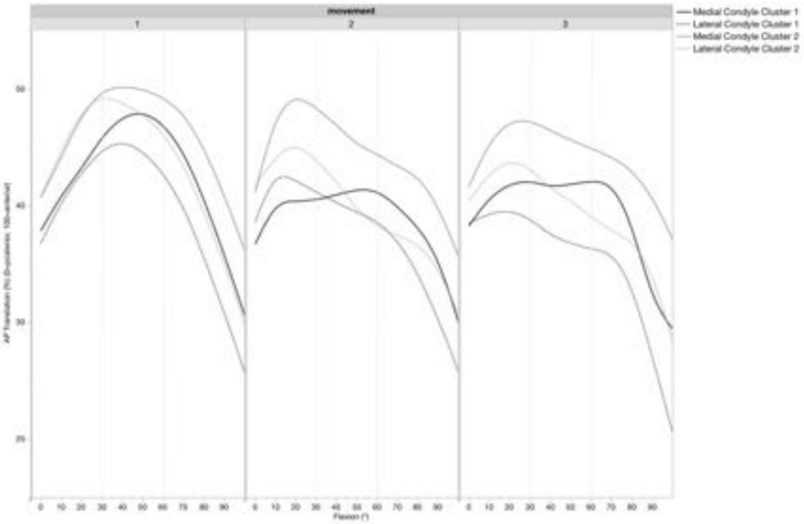
movement
1
2
3
Medial Condyle Cluster 1
Lateral Condyle Cluster 1
Medial Condyle Cluster 2
Lateral Condyle Cluster 2
50
40
30
20
0 10 20 30 40 50 60 70 80 90
Flexion (°)

Figure 1

Differential Kinematics During Stair Ascent and Descent in Medial Pivot Design Total Knee Arthroplasty

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Objective: The purposes of this study were to characterize knee kinematics in patients with a medial pivot design prosthesis when ascending and descending stairs and to compare the findings between stair ascent and descent.

Methods: ***Subjects;*** Seven patients (10 knees) who were performed total knee arthroplasty (TKA) with the Evolution® Medial-Pivot Cruciate-Retaining (CR) Knee System (MicroPort Orthopedics Inc.) and were capable of ascending and descending stairs without external assistance were studied. All the patients were women and their mean age at surgery was 67.5±3.8 years. The mean postoperative period was 31.2±6.8 months at the time when this study was conducted. The postoperative knee extension angle was -0.5±1.6 degrees, the flexion angle was 128.0±5.9 degrees, and the femorotibial angle was 174.0±2.4 degrees. ***Kinematic analysis;*** Patients were instructed to ascend and descend stairs in step-over-step manner [Fig. 1A] while serial fluoroscopic imaging was performed from the lateral direction during the stance phase (from foot contact defined as stance phase 0% to foot clearance defined as stance phase 100%). Obtained images were analyzed by using the 2-dimentional to 3-dimentional matching technique, to determine the relative 3-dimentional positions of the femoral and tibial components in each fluoroscopic image (KneeMotion; LEXI) [Fig. 1B]. The following parameters were evaluated during stair ascent and descent: the component flexion angle, anteroposterior positions at which the nearest point of the medial and lateral condyles of the femoral component relative to the tibial component, and the pattern of femoral component movement on the tibial component. ***Statistical analysis;*** In both ascending and descending stair movement, the anteroposterior positions for each medial and lateral condyle of the femoral component during each stance phase were compared by repeated-measures ANOVA with a Bonferroni post hoc test, while comparison of the maximum anteroposterior movement of the medial and lateral condyles through the full range of motion was done with the Student’s t-test.

Results: The flexion range of motion of the components while ascending the stairs ranged from 65.2±4.0 to 3.8±5.2 degrees. Maximum anteroposterior translation of the femoral component during the stance phase was 2.2±1.1 mm for the medial condyle and 5.2±1.6 mm for the lateral condyle, with translation of the medial side being significantly smaller [Fig. 2A]. The femoral component showed a medial pivot pattern in the axial movement when the subjects ascended the stairs [Fig. 3A]. When descending stairs, the flexion of the components ranged from 2.9±7.7 to 42.1±12.8 degrees. Maximum anteroposterior translation of the medial femoral condyle was significantly smaller than that of the lateral condyle, which was 1.9±0.7 mm and 2.9±1.0 mm, respectively [Fig. 2B]. However, a medial pivot pattern motion was not apparent in stair descent [Fig. 3B].

Discussion: This study demonstrated that the medial compartment is more stable than the lateral compartment when ascending and descending stairs in medial pivot CR TKA. In addition, the kinematics of stair ascent and descent was considered to be different, because medial pivot motion was observed in stair ascent but was not apparent in stair descent.

Figures

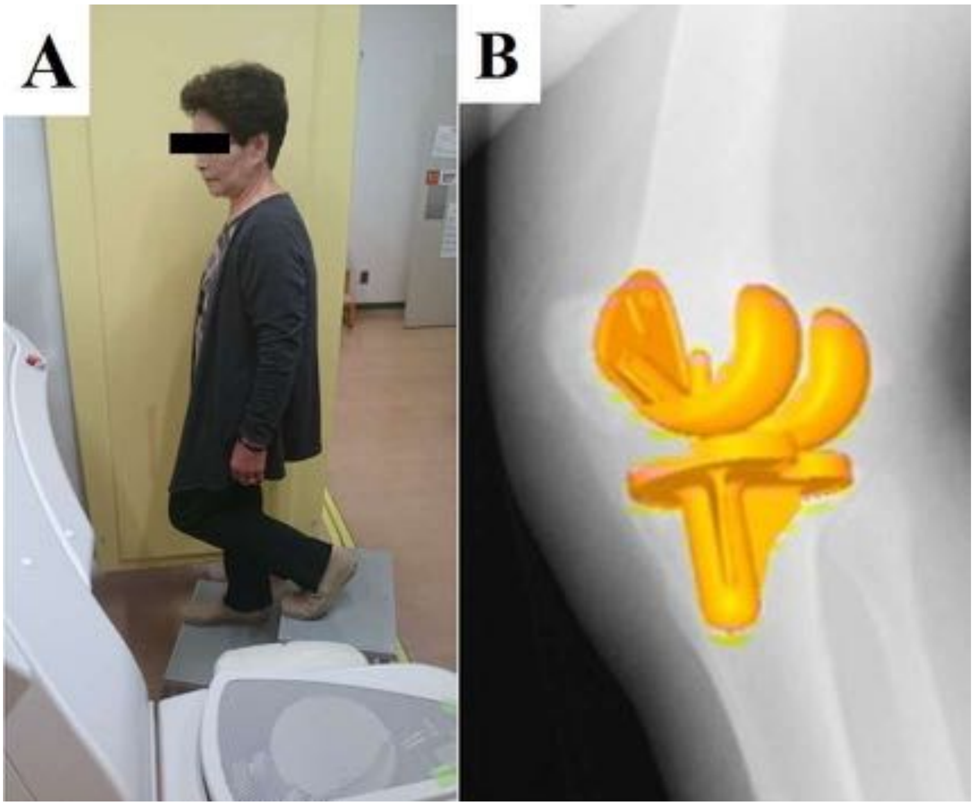

Figure 1

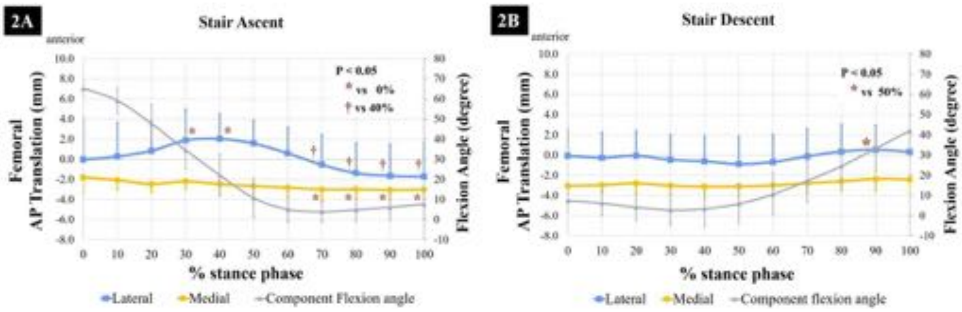

Figure 2

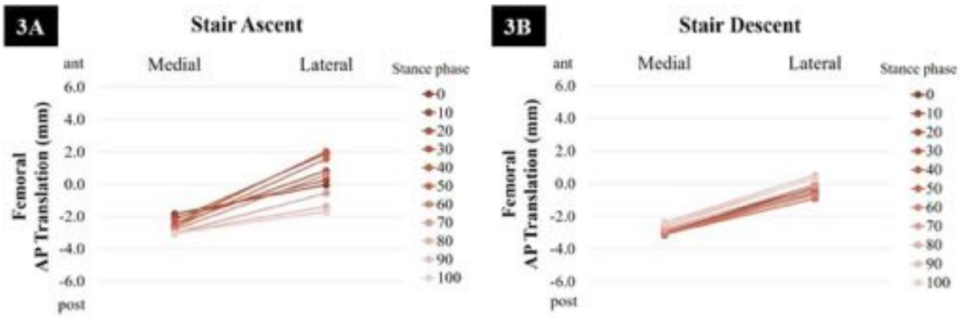

Figure 3

Rotational Soft-Tissue Balance Highly Correlates With Rotational Kinematics in Total Knee Arthroplasty

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Background: Total knee arthroplasty (TKA) is an effective treatment for knee osteoarthritis. Despite the development of modern TKA, 15 to 30% of patients are unsatisfied with their outcome. There are many factors related with the patient's satisfaction. Among them, we focused on the kinematics after TKA, especially rotational kinematics. The Rotational kinematics of normal knee shows medial pivot pattern. Recovery of this kinematics after TKA is a key factor to improve clinical results including patient satisfaction and functional outcome. However, there remain many unclear points to the recovery of normal knee kinematics after TKA. In this study, we evaluated both rotational kinematics and rotational soft-tissue balance throughout the range of motion, and assessed the correlation between soft-tissue balance and rotational kinematics.

Methods: Eighty knees treated with TKA performed with a navigation system were evaluated (cruciate-retaining (CR) TKA, 40 knees; posterior-stabilized (PS) TKA, 40 knees). Mild passive motion was applied manually while moving the leg from full extension to flexion, and the rotational angle at 0°, 30°, 45°, 60°, and 90° of flexion was automatically measured by the navigation system to evaluate rotational kinematics. In addition, maximum internal and external rotational stress was applied, and the internal-external rotational soft-tissue balance was evaluated at 0°, 30°, 45°, 60°, and 90° of flexion. The test-retest reliability of these internal-external rotational stress angle indicated that interclass and interclass correlation coefficients(ICCs) were sufficiently high, with values >0.9 at 30°, 45°, 60°, and 90° of flexion, respectively.ã€€The correlation between the rotational angle in kinematics evaluation and the median angle of internal and external rotational stress angle was assessed by Spearman's rank correlation coefficient (ρ).

Result: Soft-tissue balance (the median rotational stress angle) and rotational angle in rotational kinematics showed statistically significant high correlation (ρ: 0.66 to 0.95) at all measured angles. The correlation coefficient between soft-tissue balance and rotational angle in rotational kinematics of CR TKA was 0.95, 0.88, 0.79, 0.74 and 0.73 at 0°, 30°, 45°, 60°, and 90° of flexion, respectively and that of PS TKA was 0.96, 0.79, 0.77, 0.74 and 0.71 at 0°, 30°, 45°, 60°, and 90° of flexion, respectively. The closer to full extension, the higher the correlation coefficient was.

Conclusion: We obtained the following results: 1) there was a strong correlation between soft-tissue balance and rotational kinematics in both CR and PS procedures. Soft-tissue balance can be a key factor for recovery of normal rotational kinematics. 2) Medial stability throughout the range of motion, and lateral laxity in flexion, may play an important role in recovery of medial pivot motion after TKA.

#5804

In-Vivo, Multicenter Assessment of Knee Kinematics for Subjects Having Patient-Specific and Traditional Total Knee Arthroplasty

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Introduction: Many fluoroscopic studies on total knee arthroplasty (TKA) have identified kinematic variabilities compared to the normal knee, with many subjects experiencing paradoxical motion patterns. The intent of this research study was to investigate the results of customized-individual-made (CIM) and off-the-shelf (OTS) PS and PCR TKA to determine kinematic variabilities and to assess these kinematic patterns with those previously documented for the normal knee.

Methods: In vivo kinematics were assessed for 151 subjects – 44 with CIM-PCR, 75 with OTS-PCR, 14 with CIM-PS, and 18 with OTS-PS TKA – using a mobile fluoroscopic system and then evaluated using a 3D-2D registration technique. This was a multicenter evaluation so the group of implants were implanted by two surgeons and selected based on recruitment criteria. Each subject performed a deep knee bend activity (DKB) while under fluoroscopy. The kinematics assessed for each subject were condyle translation (LAP/MAP) and rotation (axial rotation).

Results: During the DKB, the average LAP of the CIM-PCR was -2.0 mm (s = 4.0), the OTS-PCR was -2.1 mm (s = 3.0), the CIM-PS was -9.0 mm (s = 6.0), and the OTS-PS was -4.3 mm (s = 3.3) (Figure 1). The average MAP of the CIM-PCR was 2.0 mm (s = 2.9), the OTS-PCR was 2.4 mm (s = 3.3), the CIM-PS was -1.2 mm (s = 5.2), and the OTS-PS was 1.1 mm (s = 1.7) (Figure 2). The average axial rotation of the CIM-PCR was 4.6° (s = 5.8), the OTS-PCR was 5.7° (s = 4.8), the CIM-PS was 9.3° (s = 4.8), and the OTS-PS was 7.5° (s = 3.5) (Figure 3). Eleven of 44 (25%) subjects having a CIM-PCR TKA, 16/75 (21.3%) subjects having an OTS-PCR TKA experienced an anterior slide of their lateral condyle, while no subjects having a CIM-PS TKA and 3/18 (16.6%) of OTS-PS subjects experienced this slide. Nine of 44 (20.5%) CIM-PCR, 8/75 (10.6%) OTS-PCR experienced a reverse axial rotation pattern, while only one subject having a CIM-PS and not OTS-PS subjects experienced this non-normal rotation pattern.

Discussion: Subjects having a CIM-PS TKA experienced the greatest amount of lateral condyle posterior femoral rollback and axial rotation, although less in magnitude to the normal knee seen in previous fluoroscopic studies. This was the only group to experience posterior motion of their medial condyle during flexion. More subjects having a PCR TKA experienced a paradoxical anterior lateral condyle sliding pattern and reverse axial rotation pattern, which was not commonly seen in the subjects having a PS TKA.

Significance: Subjects that had a CIM-PS TKA demonstrated greater magnitudes of lateral condyle rollback and subjects having a PS TKA experienced more normal axial rotation patterns.

Figures

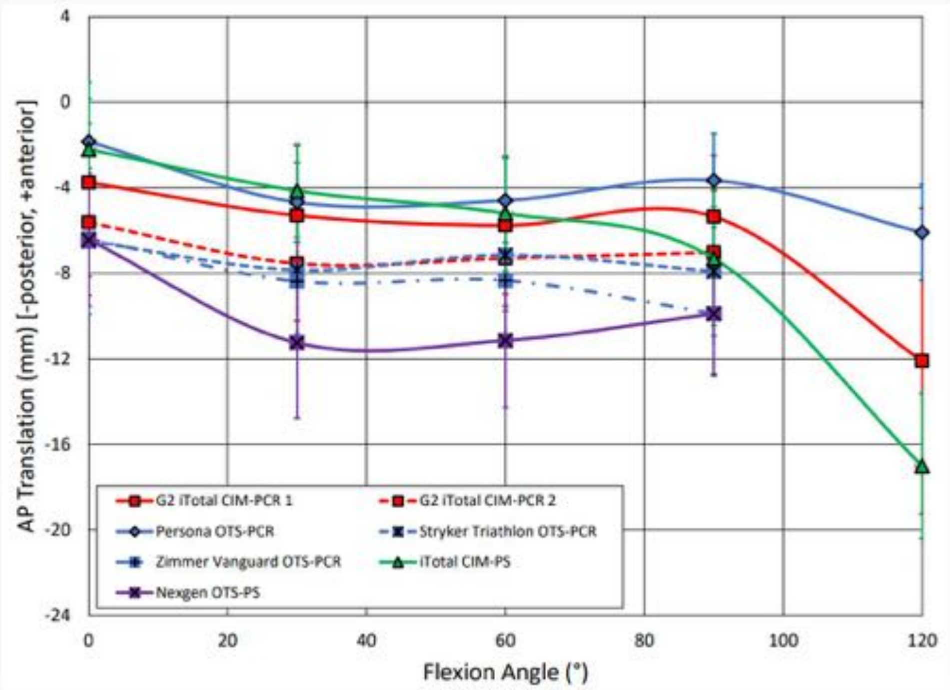

Figure 1

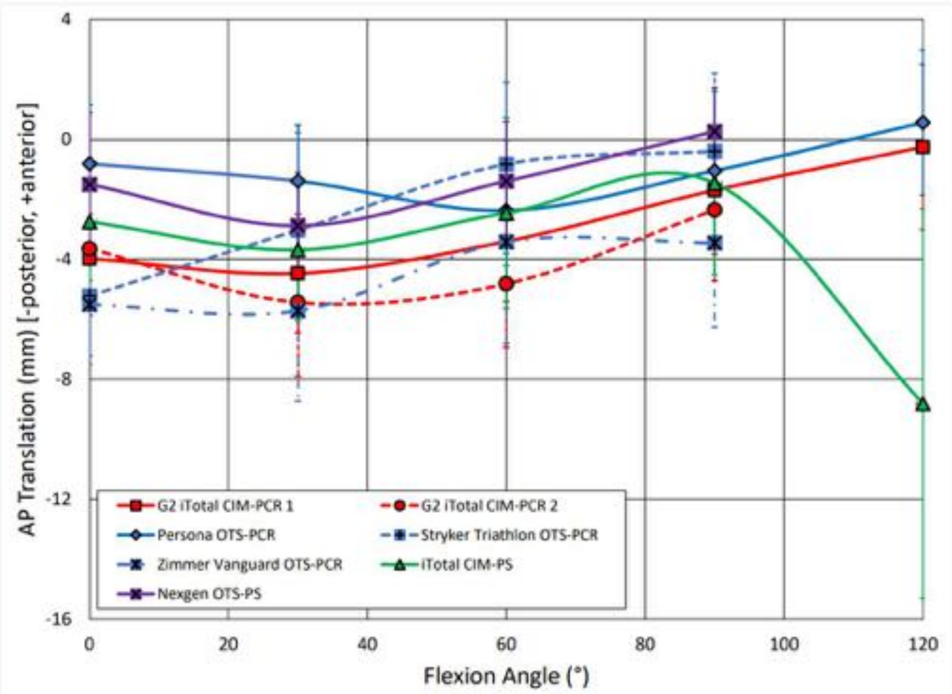

Figure 2

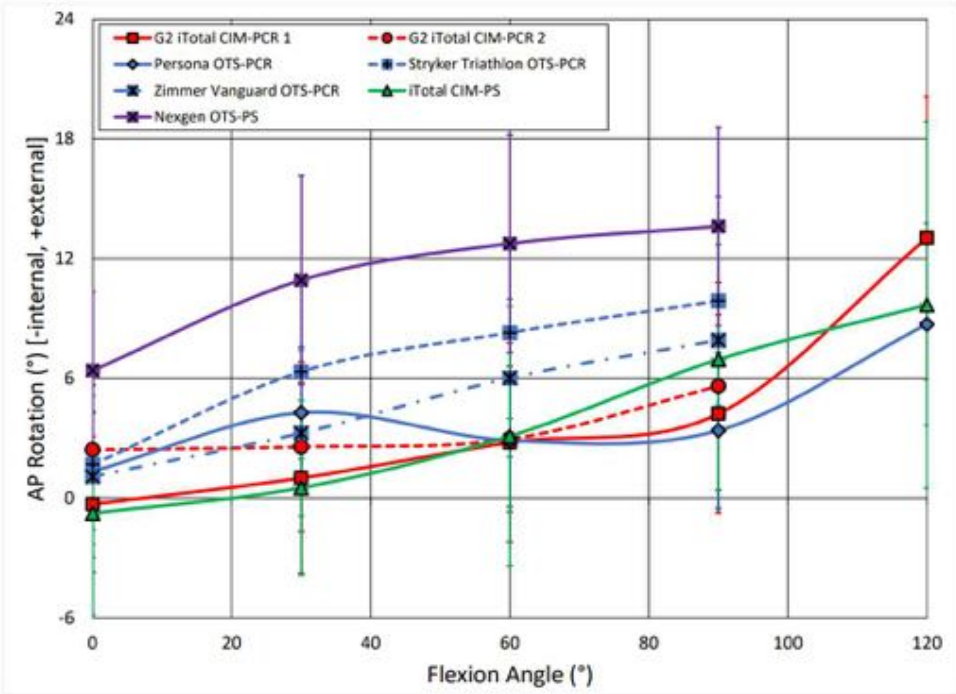
G2 iTotal CIM-PCR 1
G2 iTotal CIM-PCR 2
Persona OTS-PCR
Stryker Triathlon OTS-PCR
Zimmer Vanguard OTS-PCR
iTotal CIM-PS
Nexgen OTS-PS
AP Rotation (°) [-internal, +external]
Flexion Angle (°)
24
18
12
6
0
-6
0
20
40
60
80
100
120

Figure 3

#5885

A Comparison of Gait at a Five-Year Follow Up in Robotic Assisted vs Conventional Unicompartmental Knee Arthroplasty

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Introduction

There is a high prevalence of unicompartmental knee arthroplasty (UKA) in the UK and US [1]; demonstrating good mid-long terms results, with survival rates of ~90% at ten-years [2–4]. Recent advances in robotic surgery have led to improved alignment of UKA prostheses [5] although any improvement in function has been difficult to document as current methods are not sensitive enough to detect small but significant improvements [6]. The MAKO RIO robotic surgery system (Fort Lauderdale, Florida) has previously shown improvements in knee flexion during the weight acceptance (WA) phase of gait one-year post-operatively when compared to the conventional Oxford procedure using three dimensional gait analysis (3DGA) [7]. Therefore, the aim of this study was to determine if improvements observed at one-year remain at five-years when comparing MAKO and Oxford UKA implants.

Methods

Forty-six patients attended a five-year follow up, resulting in a total of 25 robotic assisted knees and 21 conventional knees. 3DGA was carried out using a lower-limb cluster marker model and a 10 camera Vicon Bonita optical tracking system. Participants performed a number of 10 m overground walks at a self-selected pace. A minimum of three cycles were recorded for each leg. The primary outcome measure was total excursion of the knee in the sagittal plane during WA.

Results

Figure one shows mean knee flexion for MAKO and Oxford patients. On average, MAKO patients achieved greater flexion during loading response and greater extension during mid stance at five-years.

Table 1 details mean knee flexion excursion during WA. There was a significant difference in excursion during WA (independent t-test; $\alpha = 0.05$, $P = 0.008$).

Discussion

Results demonstrated that patients in the MAKO group achieved significantly greater knee flexion excursion during WA at five-years, which is consistent with results at one-year. In normal gait, the knee must flex and extend appropriately during stance to aid shock absorption and propulsion [8]. If this is not achieved, abnormal loading patterns could lead to component wear or loosening over time. Both MAKO and Oxford implants should allow ligaments to be restored to normal function [9]; however, the MAKO system is designed to mimic bony anatomy more closely than the Oxford. Furthermore, the accuracy of prosthesis implantation provided by the MAKO system could also reduce ligamentous damage in comparison to the Oxford. Both these advantages could result in a gait pattern which facilitates the normal function of the knee more closely than the Oxford implant. These data also suggest that improvements observed at one-year follow up are likely to be maintained until at least five-years post-operatively. As this was a short-term follow-up study, outcomes should be investigated longer term (at 10–15 years) to determine the longevity of improved knee flexion in the MAKO group.

References

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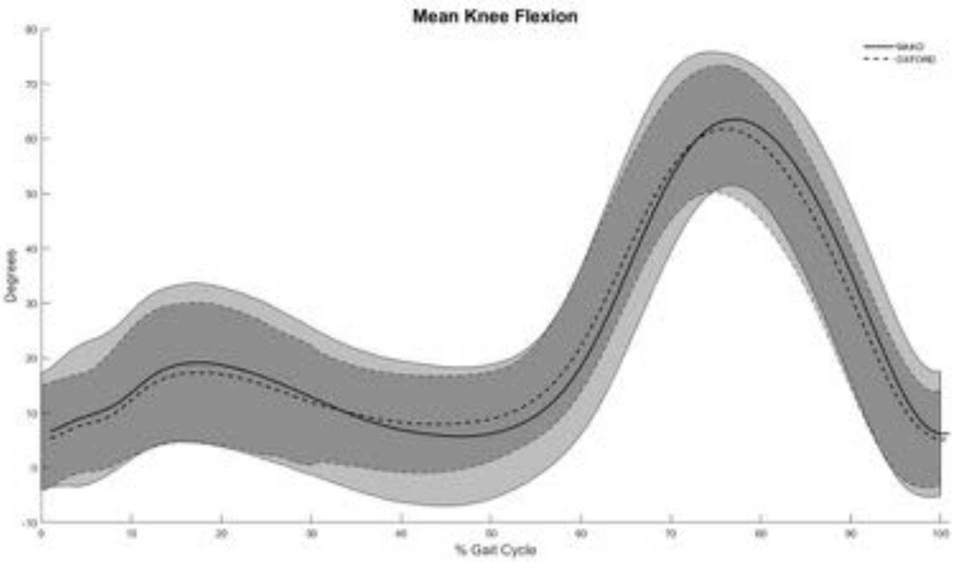
Figures



[redacted] **Figure 1.** Mean(±2SD) knee flexion for MAKO (solid) and Oxford (dashed) patients.

Figure 1

Table 1. Mean (SD) excursion during weight acceptance for each patient group

[redacted]

Figure 2

#5505

Motion Analysis of Kneeling After Total Knee Arthroplasty With Ball and Socket Joint

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[Purpose**]** In the Japanese lifestyle, kneeling is one of the important activities of daily living and has a considerable impact on patient satisfaction after total knee arthroplasty (TKA). The purpose of this study was to conduct motion analysis of kneeling after TKA using Bi-Surface®5, a knee implant designed with a ball-and-socket joint structure, and evaluate its effectiveness in kneeling.

[Subjects and methods**]** The study included 19 knees (1 male joint and 18 female joints) after first-time TKA. The mean age of the patients was 79 years and their mean age at the time of surgery was 79 (71-87) years. The primary disease was knee osteoarthritis in 18 knees and rheumatoid arthritis in 1 knee. The type of prosthesis used was the posterior stabilized type (PS type) in 9 knees and the posterior cruciate-sacrifice type (CS type) in 10 knees. Plain lateral knee radiographs were taken with the patients sitting with the knee at 90-degree flexion, kneeling with the knee at 90-degree flexion, and kneeling with the knee in maximal flexion (maximal kneeling). The images were taken 3 and 6 months after TKA. Using 3D to 2D registration technique,these images were analyzed in terms of positional relationships of the knee components.

[Results and discussion**]** During kneeling at 90 degrees of flexion, forward movement was more restricted in knees with the PS type than those with the CS type, indicating that the post-cam mechanism was functioning. During kneeling at 90 degrees of flexion, the contact point on the post was at its base and therefore, a post fracture was considered less likely. In maximal kneeling, the ball-and-socket mechanism was functioning in both CS and PS types.

#5848

Effect of Patellar Shape to the Kinematics of Tibiofemoral and Patellofemoral Joint: Model Analysis

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Many recent knee prostheses are designed aiming to the physiological knee kinematics on tibiofemoral joint, which means the femoral rollback and medial pivot motion. However, there have been few studies how to design a patellar component. Since patella and tibia are connected by a patellar tendon, tibiofemoral and patellofemoral motion or contact forces might affect each other. In this study, we aimed to discuss the optimal design of patellar component and simulated the knee flexion using four types of patellar shape during deep knee flexion.

Our simulation model calculates the position/orientation, contact points and contact forces by inputting knee flexion angle, muscle forces and external forces. It can be separated into patellofemoral and tibiofemoral joints. On each joint, calculations are performed using the condition of point contact and force/moment equilibrium. First, patellofemoral was calculated and output patellar tendon force, and tibiofemoral was calculated with patellar tendon force as external force. Then patellofemoral was calculated again, and the calculation was repeated until the position/orientation of tibia converged.

We tried four types of patellar shape shown in Fig.1. Femoral and tibial surfaces are created from Scorpio NRG PS (Stryker Co.). Condition of knee flexion was passive, with constant muscle forces and varying external force acting on tibia. Knee flexion angle was from 80 to 150 degrees.

As a result, the internal rotation of tibia varied much by using anatomical or plate patella than dome or cylinder shape, as shown in Fig.2. Although patellar contact force did not change much, tibial contact balances were better on dome and cylinder patella and the medial contact forces were larger than lateral on anatomical and plate patella. Thus, the results could be divided into two types, dome/cylinder and plate/anatomical. It might be caused by the variations of patellar rotation angle were large on anatomical and plate patella, though patellar tilt angles were similar in all the cases, as shown in Fig.3. We have already reported that the anatomical shape of patella would contact in good medial-lateral balance when tibia moved physiologically, therefore we have predicted the anatomical patella might facilitate the physiological tibiofemoral motion. However, the results were not as we predicted. Actually our previous and this study are not in the same condition; we used a posterior-stabilized type of prosthesis, and the post and cam mechanism could not make the femur roll back during deep knee flexion.

It might be better to choose dome or cylinder patella to obtain the stability of tibiofemoral joint, and to choose anatomical or plate to the mobility.

Figures

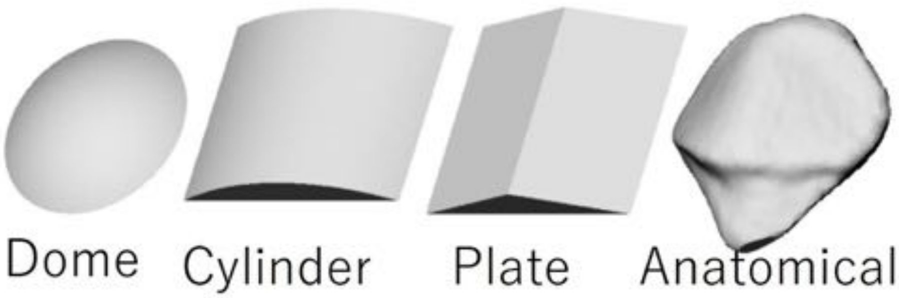

Figure 1

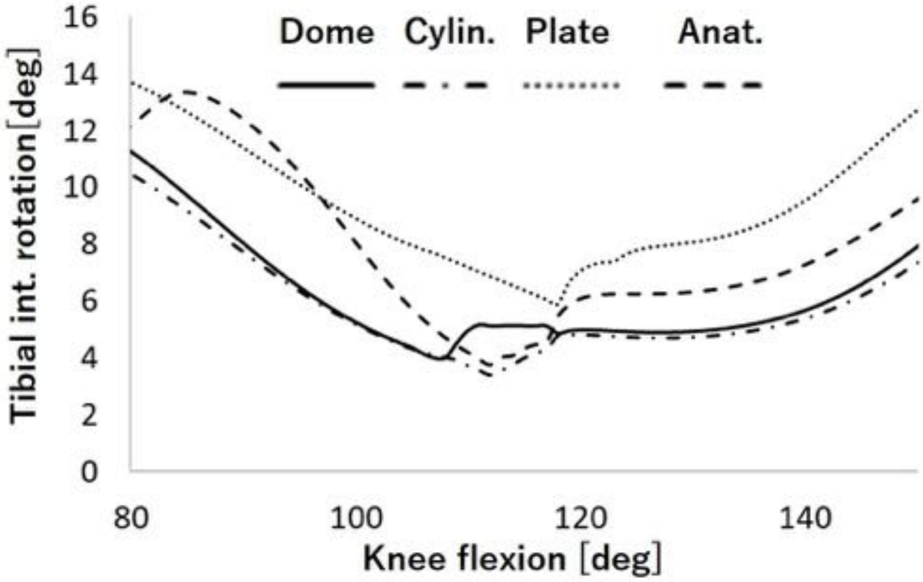

Figure 2

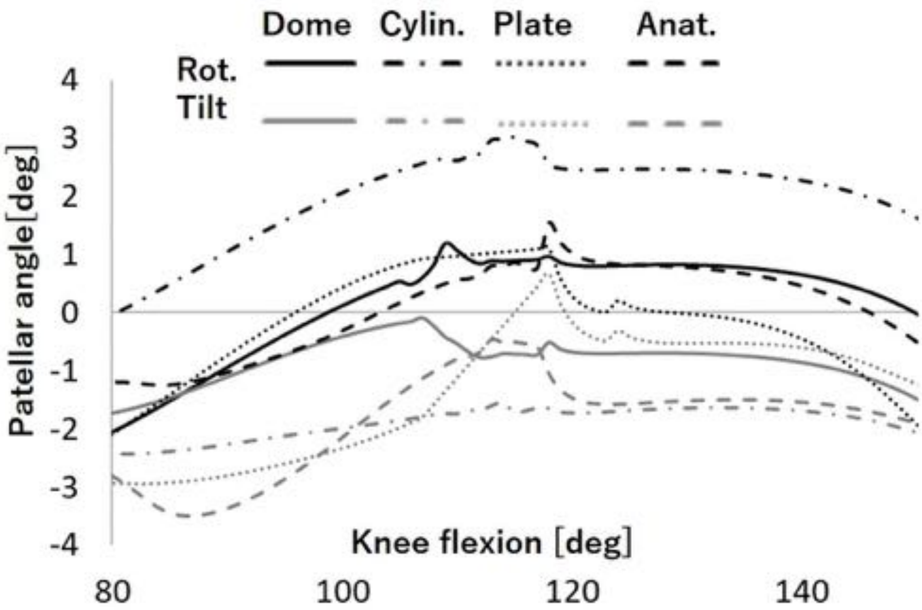

Figure 3

Extraction Force Is Not an Indicator for Primary Stability of Cementless Tibial Trays

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Introduction

In total knee arthroplasty (TKA), cementless implants rely on initial fixation to stabilize the implant in order to facilitate biologic fixation. Initial fixation of cementless tibias has typically been quantified by micromotion between the implant and underlying bone during loading. Extraction force, related to press-fit of the fixation features for tray designs without screws, has been proposed as a predictor of initial fixation. However, there are several other factors that may more meaningfully affect the initial fixation of a cementless tibial tray, including but not limited to, shape of the implant and the tray being flush to the bone. The objective of this research was to rank the significance of each factor with regard to its effect on tibial tray micromotion.

Methods

All tibial trays tested were evaluated using a new method that experimentally applies a full, six degree of freedom, level walking cycle to cementless implants in a bone analog. Input kinetics were based on loads and moments measured directly from telemetrized implants [1-Kutzner]. These inputs were deployed in the test via a six axis robot arm, capable of applying physiologic loading to the tibial trays representing the full functional activity (Figure 1).

Four different configurations were tested in all. Three configurations used an anatomically-shaped tibial tray and included: implant seated flush to bone surrogate with nominal press-fit (Anatomic, n=6), implant seated flush to bone surrogate with removed press-fit (Extraction force, n=5), and implants intentionally seated 0.8mm proud with acrylic standoffs in order to simulate a non-seated implant (Proud, n=6). The last configuration used a flush symmetric tibial tray with similar fixation features as the other tray tested and nominal press-fit (Symmetric, n=6). The reduced extraction force group had less than 10% of the extraction force of the nominal groups. A cruciate retaining polyethylene insert and mating femoral component were used for all of the testing. A composite asymmetric synthetic bone analog was used for this evaluation. Digital image correlation was used to measure the micromotion of the tray with respect to the bone analog.

An analogous finite element (FE) model was developed to represent the test method, deploying the same kinetic and kinematic representation of walking gait as the robotic testing (Figure 2). Material properties and interface press-fit conditions were based on direct measurements of foam stiffness and pull-out loads, respectively.

Results

The anatomically shaped tibial tray with nominal press-fit was found to have the smallest maximum total micromotion and the proud anatomically shaped tibial tray was found to have the highest maximum total micromotion (Figure 3). Tray design (4x) and tray positioning (10x) were dominant effects; reduced extraction force (~1x) had minimal influence on micromotion. FE predictions closely mirrored those measured from the benchtop test.

Discussion

Of the design and surgical factors examined here, sufficient seating of the tray and tray shape were most impactful on micromotion. Reducing the extraction force was found to have minimal effects on the total micromotion of the anatomically shaped tibial tray when subjected to loading characteristic of human gait. Extraction force is thus not a clinically relevant indicator of primary stability.

Figures

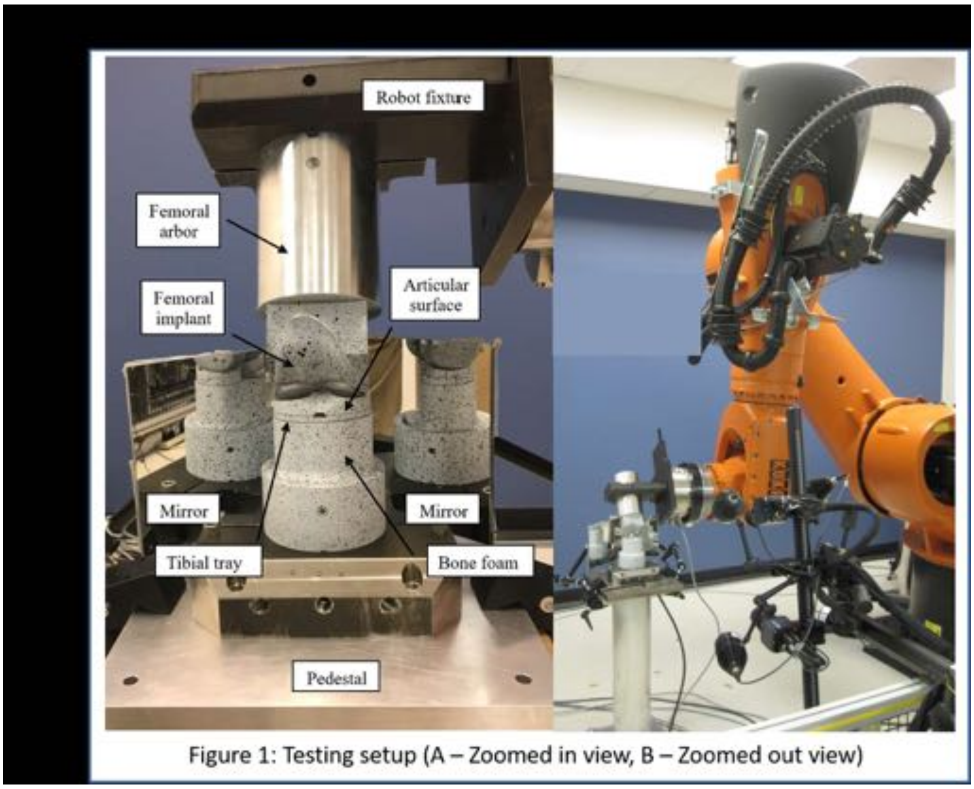

Figure 1: Testing setup (A – Zoomed in view, B – Zoomed out view)

Figure 1

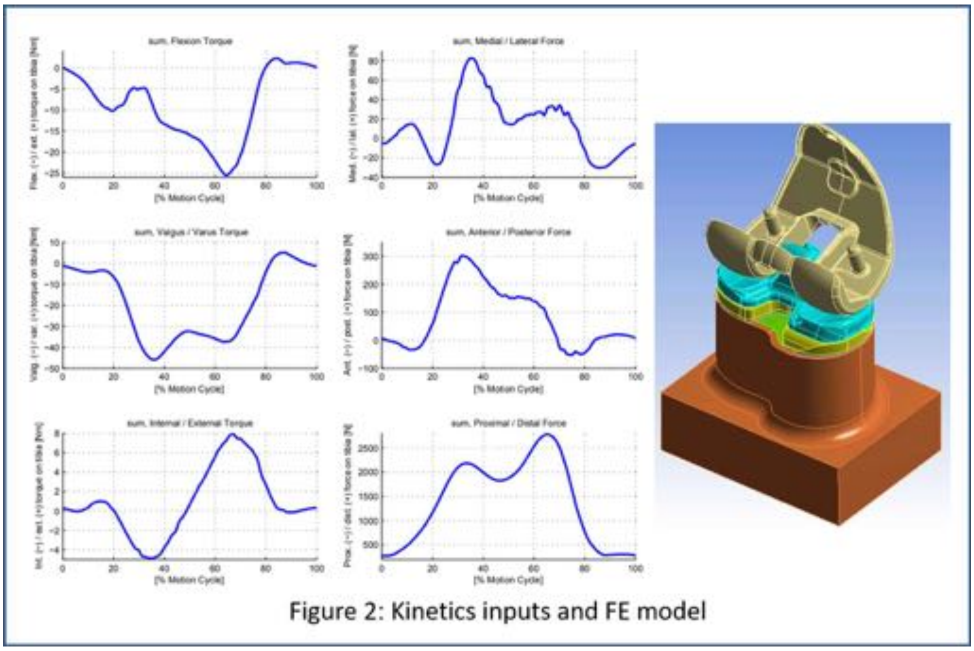
Figure 2: Kinetics inputs and FE model

Figure 2

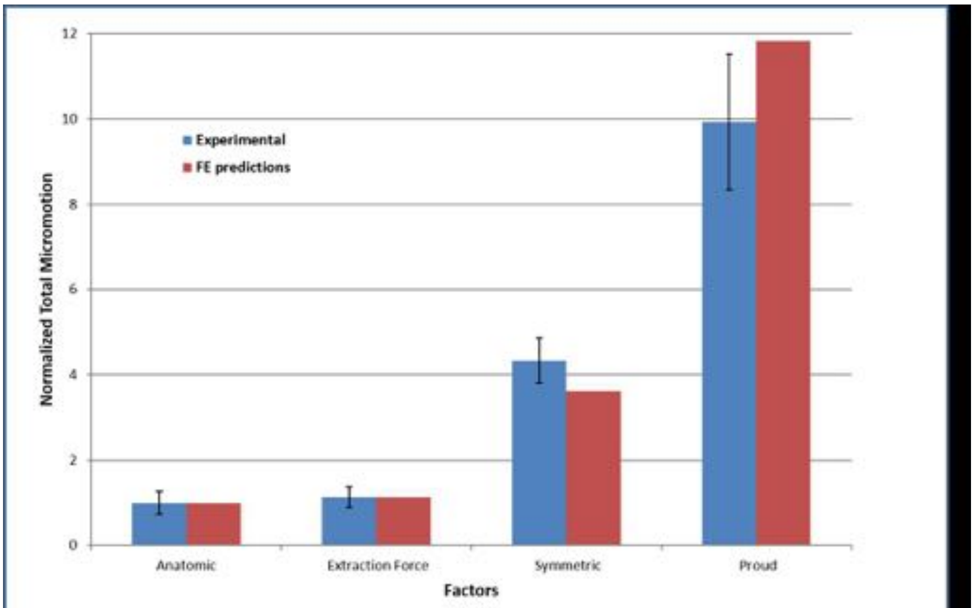

Figure 3: Effect of different factors on total micromotion (error bars represent standard deviations)

Figure 3

#6139

Influence of Physiological Loading Following Intra-Operative Lipid/Marrow Infiltration and Intra-Operative Motions Upon Micromotion

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Introduction:

Aseptic loosening of total knee replacements is a leading cause for revision. It is known that micromotion has an influence on the loosening of cemented implants though it is not yet well understood what the effect of repeated physiological loading has on the micromotion between implants and cement mantle [1]. This study aims to investigate effect of physiological loading on the stability of tibial implants previously subjected to simulated intra-operative lipid/marrow infiltration.

Methods:

Three commercially available fixed bearing tibial implant designs were investigated in this study: ATTUNE®, PFC SIGMA® CoCr, ATTUNE® S+. The implant designs were first prepared using a LMI implantation process. Following the method described by Maag et al [3] tibial implants were cemented in a bone analog with 2 mL of bone marrow in the distal cavity and an additional reservoir of lipid adjacent to the posterior edge of the implant. The samples were subjected to intra-operative range of motion (ROM)/stability evaluation using an AMTI VIVO simulator, then a hyperextension activity until 15 minutes of cement cure time, and finally 3 additional ROM/stability evaluations were performed.

Implant specific physiological loading was determined using telemetric tibial implant data from Orthoload [3] and applying it to a validated FE lower limb model developed by the University of Denver [4]. Two high demand activities were selected for the loading section of this study: step down (SD) and deep knee bend (DKB). Using the above model, 6 degree of freedom kinetics and kinematics for each activity was determined for each posterior stabilized implant design.

Prior to loading, the 3-D motion between tibial implant and bone analog (micromotion) was measured using an ARAMIS Digital Image Correlation (DIC) system. Measurement was taken during the simulated DKB at 0.25Hz using an AMTI VIVO simulator while the DIC system captured images at a frame rate of 10Hz [Fig.1]. The GOM software calculated the distance between reference point markers applied to the posterior implant and foam bone [Fig.2]. A Matlab program calculated maximum micromotion within each DKB cycle and averaged that value across five cycles.

The implant specific loading parameters were then applied to the three tibial implant designs. Using an AMTI VIVO simulator each sample was subjected to 50,000 DKB and 120,000 SD cycles at 0.8Hz in series; equating to approximately 2 years of physiological activity. Following loading, micromotion was measured using the same method as above.

Results:

Initial micomotion measurements during DKB activity for ATTUNE®, PFC SIGMA® CoCr, ATTUNE® S+ were 155μm, 246μm, and 104μm, respectively, and following physiological loading were 159µm, 264µm, and 112µm, respectively. While there was statistical significance between the micromotion of implant designs ($p<0.05$), there was no significance between before and after loading [Fig.3].

Conclusion:

This study shows there is no significant change in micromotion after approximately 2 years of physiological loading. However, there is a significant difference in micromotion between implant designs.

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[3] Bergmann (Ed.), 2008 <http://Orthoload.com>.

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Figures

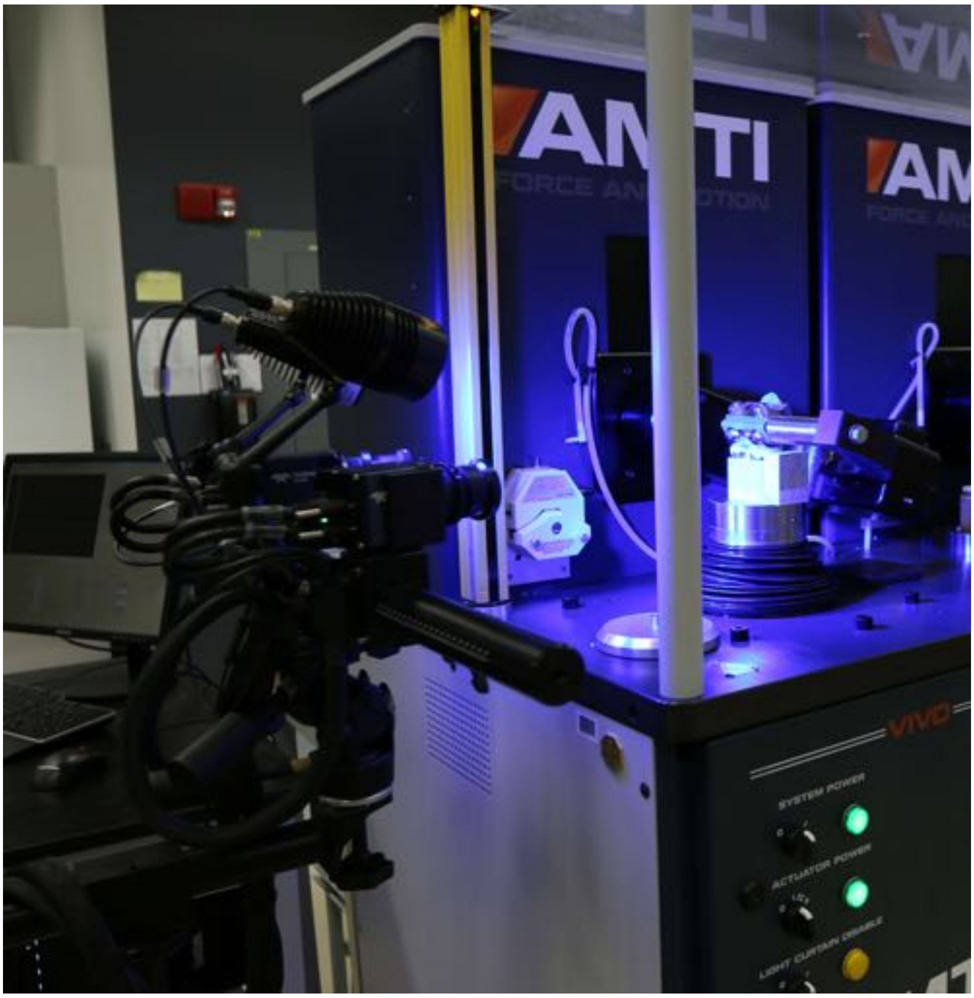
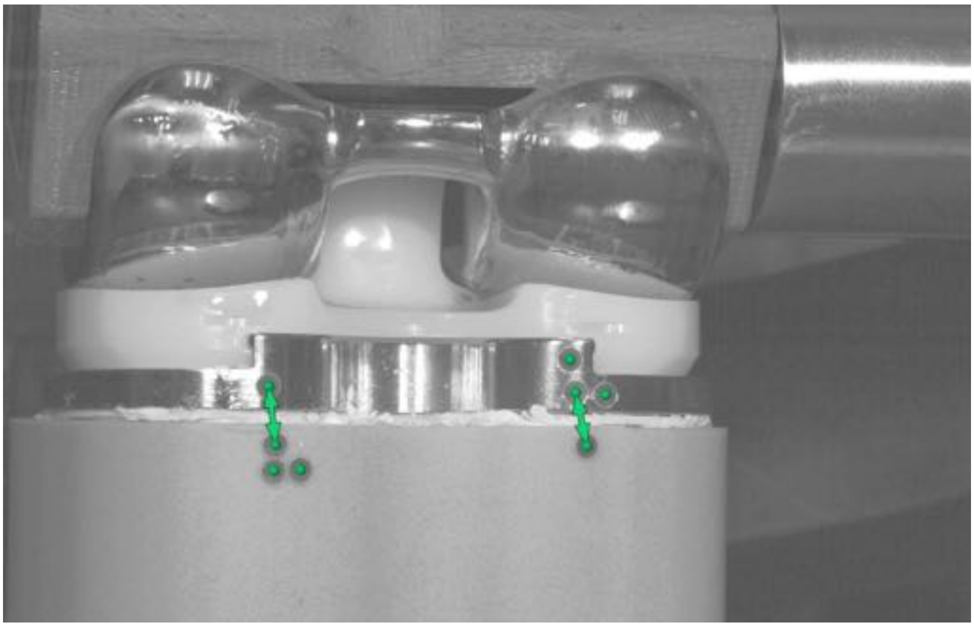


Figure 1



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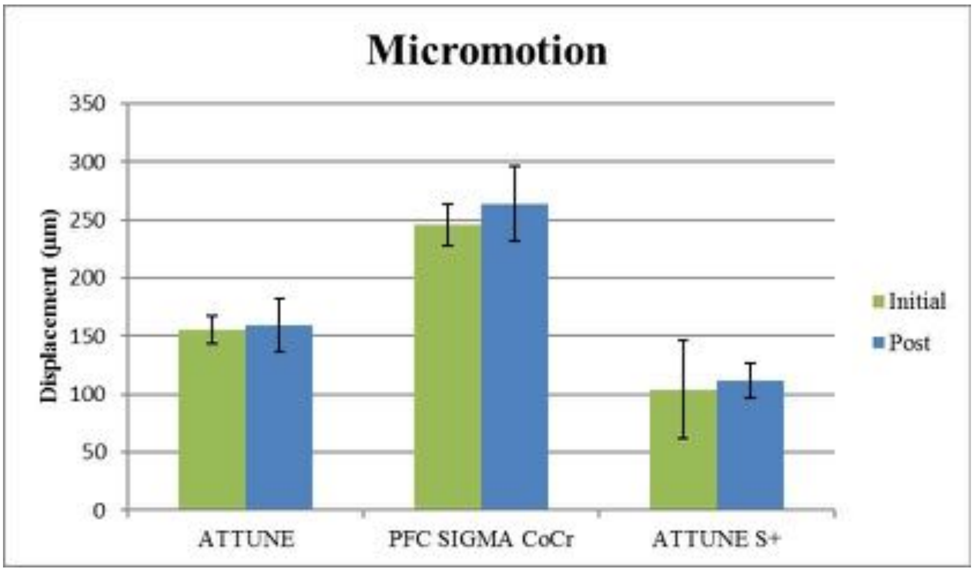

Figure 3

#5793

Distribution of Bone on-Growth in Tibial Metaphyseal Sleeves: A Retrieval Analysis

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Background: Porous titanium tibial metaphyseal sleeves are used to manage bone loss encountered during revision total knee arthroplasty. While short-term results concerning tibial metaphyseal sleeve use have been encouraging, little is known about the extent of long-term biologic fixation.

Question/Purposes: The purposes of this study were to: (1) determine the extent of biologic fixation on a series of retrieved tibial sleeves and (2) define which factors might influence the degree of biologic fixation observed in the retrieved specimens.

Methods: We retrospectively studied 16 patients (16 sleeves) who had undergone revision total knee arthroplasty resulting in removal of the tibial metaphyseal sleeves at an average of 52 months from their index procedure. Clinical and demographic data were obtained from the patient's electronic health records. Pre-revision radiographs were reviewed for extent of biologic fixation to the sleeves, additionally, the stem canal-fill ratio was recorded. The implants were examined using stereomicroscopic techniques to record the extent of biologic fixation. These regions were then mapped using Adobe Photoshop (Fig 1).

Results: Bone on-growth covered on average 13.1% of the entire porous surface of the tibial sleeves. The anterior and lateral surfaces (16.1% and 18.3%) had a significantly greater proportion of bone on-growth compared to the medial and posterior surfaces (10.1% and 8.1%) ($p < 0.05$). Technical factors such as stem canal-fill ratio and the presence of cement on the porous surface did not correlate with distribution or percentage of bone on-growth. Radiographic signs for biologic fixation poorly predicted bone on-growth in the retrieved specimens. Additionally, age, length of implantation, and body mass index did not influence the pattern of biologic fixation.

Conclusions: The retrieved porous titanium tibial metaphyseal sleeves demonstrated a modest amount of biologic fixation. While the literature continues to encourage their use, additional studies are warranted to further understand factors that influence the potential for long term durability of tibial metaphyseal sleeves.

Figures

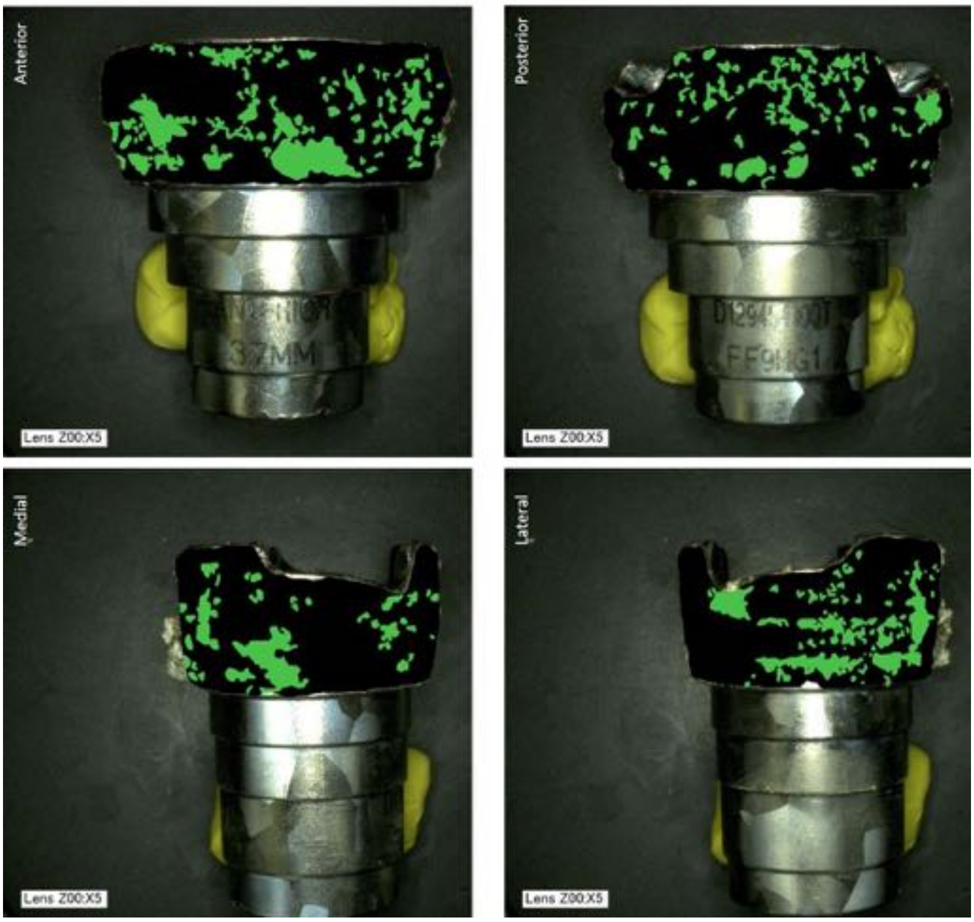
Anterior
Lens Z00:X5
Posterior
Lens Z00:X5
Medial
Lens Z00:X5
Lateral
Lens Z00:X5

Figure 1

#5995

Ps Devices Are Not Worst Case for Tray Fixation in Cementless Tka

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INTRODUCTION

Posterior stabilized implants are frequently used to assess the fixation of cementless tibial trays [1-3], presumably due to the perception that the added constraint in the prosthesis results in a more extreme state of loading. Other assessments have ignored the influence of constraint [4]. No studies have been performed to demonstrate the influence of articulation constraint on cementless tibial tray fixation. The goal of this study was to evaluate micromotion of a cementless tray using a range of polyethylene constraints, in order to challenge the assumption that increased constraint results in increased micromotion.

METHODS

Six degree of freedom robotic testing was performed on a cadaveric knee to assess the laxity of the knee and its constituents. A specimen specific computational model of the knee was developed and calibrated to the laxity data, with validity established by demonstrating the ability to predict the knee kinematics [5]. Kinetics associated with walking gait were used to establish tibiofemoral contact patterns for cruciate retaining (CR), medial congruent (MC), ultracongruent (UC), and posterior stabilized (PS) articular surfaces on an anatomic tibial tray. All components were evaluated at their indicated tibial slopes, with the PCL intact in the CR and MC evaluations.

Contact patterns were applied to a primary stability model of the tibial tray. Each model included the articular surface, a common anatomic tibial tray with fixation pegs, and a bone model consisting of a stiff cortical rim and an interior cancellous region (Fig. 1). Material properties for constituent materials, and for interface conditions between pegs and bone, were calculated from compression tests and pull-out tests, respectively. Resulting micromotion was calculated as the peak three-dimensional relative motion on the interface between tray and bone.

RESULTS

Peak micromotion for all constraints occurred at time points during gait of high effective joint reaction force and varus/valgus moment. Contact patterns at these time points demonstrated more posterior loading on the medial side of the articular surface (Fig. 2). Peak micromotion was associated with posteriormedial subsidence and anteriorlateral liftoff. Micromotion profiles during gait showed elevated peak micromotions for the CR and MC constraints, relative to the other constraints (Fig. 3).

DISCUSSION

The influence of constraint at the articulation on tray fixation in cementless TKA is unknown. Here, we show that for a common tray design, posterior medial loading is the primary determinant for the micromotion profile, resulting in posteriormedial subsidence and anteriorlateral liftoff that is significantly greater for the CR and MC designs than for the other constraints (UC and PS). This suggests that tibial slope and the presence of the PCL are important considerations when evaluating primary stability. Further work on additional tray designs and additional functional activities will confirm whether this counter-intuitive result is singular to the designs and activity pattern considered here, or is a more general characteristic of cementless TKA.

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[3] Stoller A, ORS Annual Meeting, 2013.

[3] Fitzpatrick CK, J Biomech, 2014.

[4] Siggelkow E, ASME SBC, 2012.

<u>Figures</u>

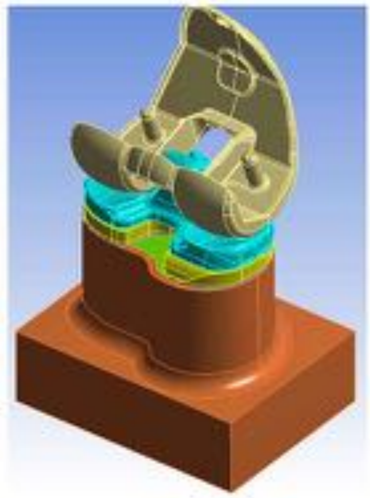

Figure 1: *Schematic of the micromotion model setup for assessing fixation at the tray-bone interface.*

Figure 1

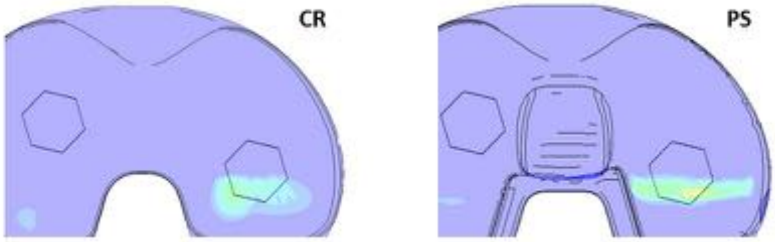

Figure 2. *Contact patterns for CR (left) and PS (right) designs at maximum posterior medial loading. Hexagonal profiles of fixation pegs are shown for reference.*

Figure 2

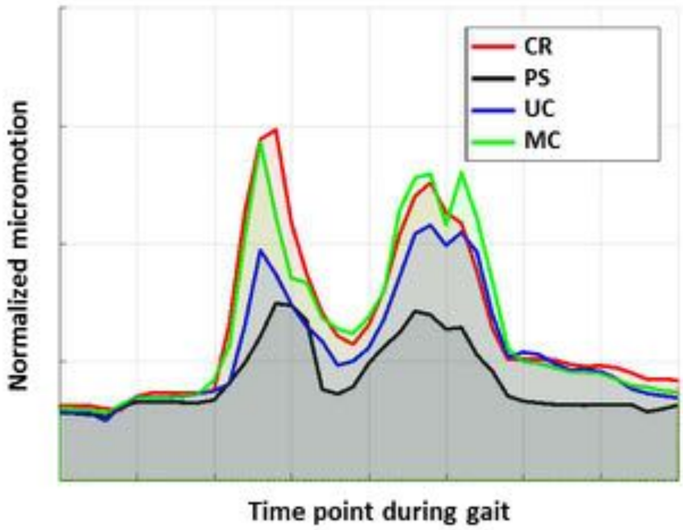

Figure 3. *Peak normalized micromotion for all constraints during gait.*

Figure 3

#5787

Does Drill Design Affect the Implantation of a Cementless Tibia Tray?

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Introduction

Cementless total knee arthroplasty (TKA) designs are clinically successful and allow for long term biological fixation. Utilizing morselized bone to promote biological fixation is a strategy in cementless implantation. However, it is unknown how bone debris influences the initial placement of the tray. Recent findings show that unseated tibia trays without good contact with the tibial resection experience increased motion. This current study focuses on the effect of technique and instrument design on the initial implantation of a cementless porous tibia. Specifically, can technique or instrument design influence generation of bone debris, and thereby change the forces required to fully seat a cementless tray with pegs?

Methods

This bench top test measured the force-displacement curve during controlled insertion of a modern cementless tibia plate with two fixation pegs. A total of nine pairs of stripped human cadaver tibias were prepared according to the surgical technique. However, the holes for the fixation pegs were drilled intentionally shallow to isolate changes in insertion force due to the hole preparation. A first generation instrument set (Instrument 1.0) and new instrument set design (Instrument 2.0), including a new drill bit designed to remove debris from the peg hole, were used (Figure 1). The tibias prepared with Instrument 1.0 were either cleaned to remove bone debris from the holes or not cleaned. The tibias prepared with the Instrument 2.0 instruments were not cleaned, resulting in three groups: Instrument 1.0 (n=7), Instrument 1.0 Cleaned (n=5), and Instrument 2.0 (n=6). Following tibia resection and preparation of holes for the fixation pegs, the tibias were cut and potted in bone cement ensuring the osteotomy was horizontal. The tibial tray was mounted in a load frame (Enduratec) and the trays were inserted at a constant rate (0.169mm/sec) while recording the force. The test was concluded when the pegs were clearly past the bottom of the intentionally shallow holes.

Results

The force-displacement curves from this method were dependent on the instrument used and cleaning of the holes (Figure 2). Instrument 2.0 specimens were inserted about 2 mm past the maximum peg depth before experiencing a significant increased resistance. The Instrument 1.0 Cleaned holes saw an increase in force slightly past the maximum peg depth, while the Instrument 1.0 group saw increase in force around 1 mm before reaching the maximum peg depth. The average insertion force required to reach maximum peg depth was significantly higher for the Instrument 1.0 group than both the Instrument 1.0 Cleaned and the Instrument 2.0 group (Figure 3). The insertion forces at a ‘mid-tunnel’ location, before the increase in resistance, were not affected by drill design as the drill diameters were the same, resulting in the same press fit.

Conclusions

Bone debris in fixation feature holes increases the force to fully seat a cementless tibia plate. This suggests there is a cost to leaving morselized bone in place. Removing bone debris through instrument design or surgical technique can ensure that a tibial plate is fully seated at time of implantation, maximizing initial fixation.

Figures

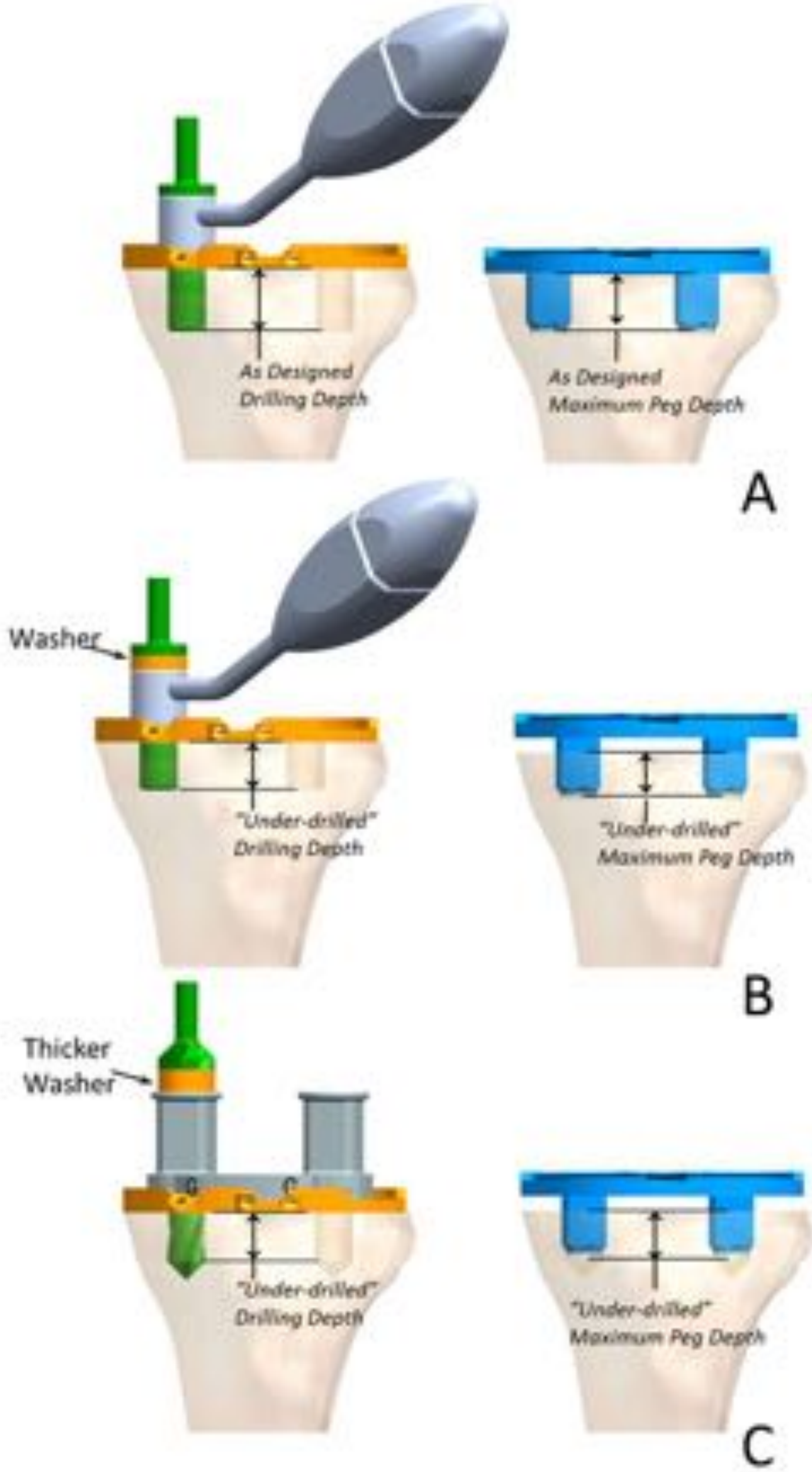

Figure 1: As designed, the drill depth for Instrument 1.0 is enough to allow for some space beneath pegs and the tray to fully seat on the tibial resection (A). In these experiments the holes were drilled shallow to isolate resistance in the peg holes: Instrument 1.0 (B) and Instrument 2.0 (C)

Figure 1

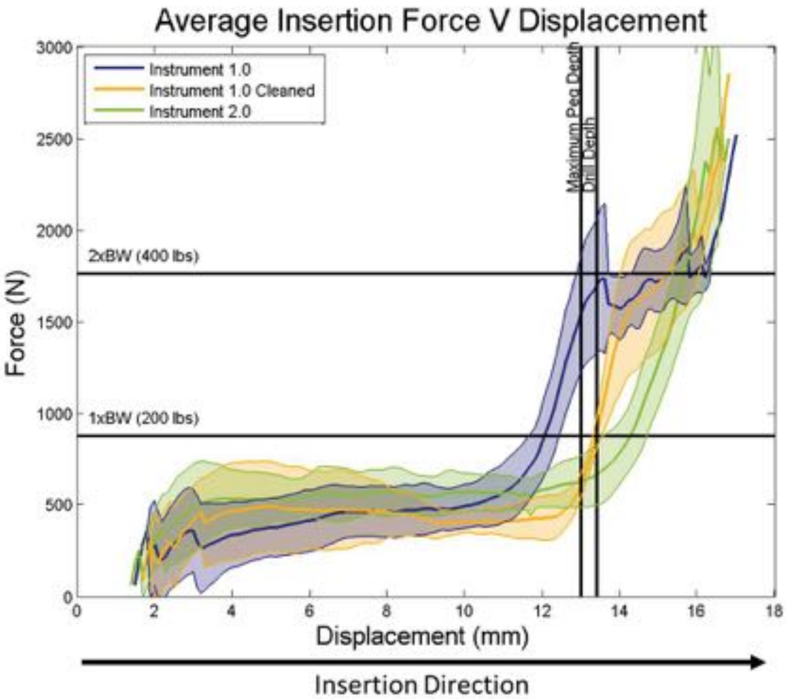

Figure 2: Force-displacement curves for Instrument 1.0, Instrument 1.0 Cleaned and Instrument 2.0 groups..

Figure 2

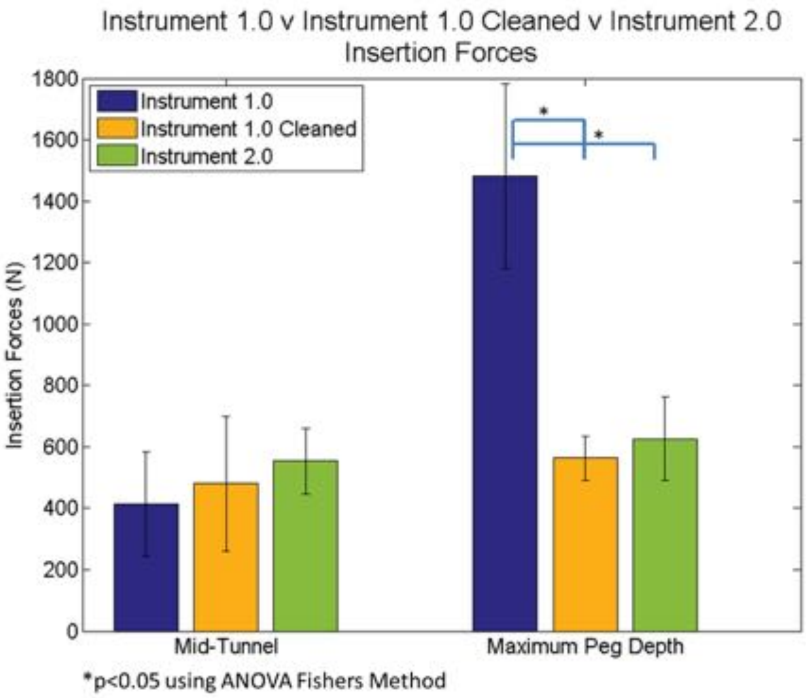

Figure 3: Bar chart displaying average forces for three groups at a mid-tunnel position during insertion and at the maximum peg depth.

Figure 3

#5990

Does Implant Fixation Affect Early Return to Function Following Primary Total Knee Arthroplasty?

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Introduction: While cementless TKA provides an alternative to the standard cemented TKA, the impact of fixation type on postoperative function is not well known. Thus, we compared early postoperative function between cementless and cemented TKA using the same implant design.

Methods: In a prospective, non-randomized trial, 373 knees in 319 subjects at 10 centers received a single cementless total knee system including cementless metal-backed patellae (Cohort 1) and 146 knees in 133 subjects received a cemented version of the same design (Cohort 2). The new Knee Society Score (KSS-2011), Oxford Knee Score (OKS), and radiographs were collected preoperatively and through 1 year of follow-up.

Results: Skin-to-skin time was lower ($p < 0.0001$) in Cohort 1 than Cohort 2. No differences were observed in adverse event rates or implant survivorship at one year follow-up. At six weeks, statistically significant ($p < 0.05$) differences were identified between the two cohorts in the KSS Function score and sub-scales (Table 1), as well as individual functional questions within the KSS and OKS (Figure 1), with the patients in Cohort 1 achieving higher levels of function. This trend continued at six months, with slight variation. The level of patient function was observed to equalize between the two cohorts at one year postoperative. Statistically significant differences remained only in the proportions of patients who were satisfied with their level of function while performing light household duties and their ability to go grocery shopping alone with little to no difficulty.

Conclusions: In a series of cementless TKAs, we observed shorter operative times and improved early patient satisfaction compared to cemented components. While cementless and cemented fixation provided similar positive outcomes at one year, our results suggest that cementless TKA may provide faster return to function, corresponding to increased patient satisfaction in the early postoperative period. Longer term follow up is required to confirm continued implant survivorship and favorable outcomes.

Figures

Table 1. Mean KSS Function Scores	6 weeks		6 months		1 year	
	Cohort 1	Cohort 2	Cohort 1	Cohort 2	Cohort 1	Cohort 2
KSS Function Score	51.50*	45.75	70.31*	67.07	78.20	72.71
Walking/Standing Subscale^	16.37*	14.61	23.02	21.73	25.68	23.83
Standard Activities Subscale	20.36*	18.80	23.71*	22.67	25.39	23.73
Advanced Activities Subscale	7.99*	6.18	12.71	12.39	14.74	13.77
Discretionary Knee Activities Subscale	7.04*	6.00	11.05*	10.35	12.46	11.33

*Statistically significantly higher
^Statistically significant difference preoperatively

Figure 1

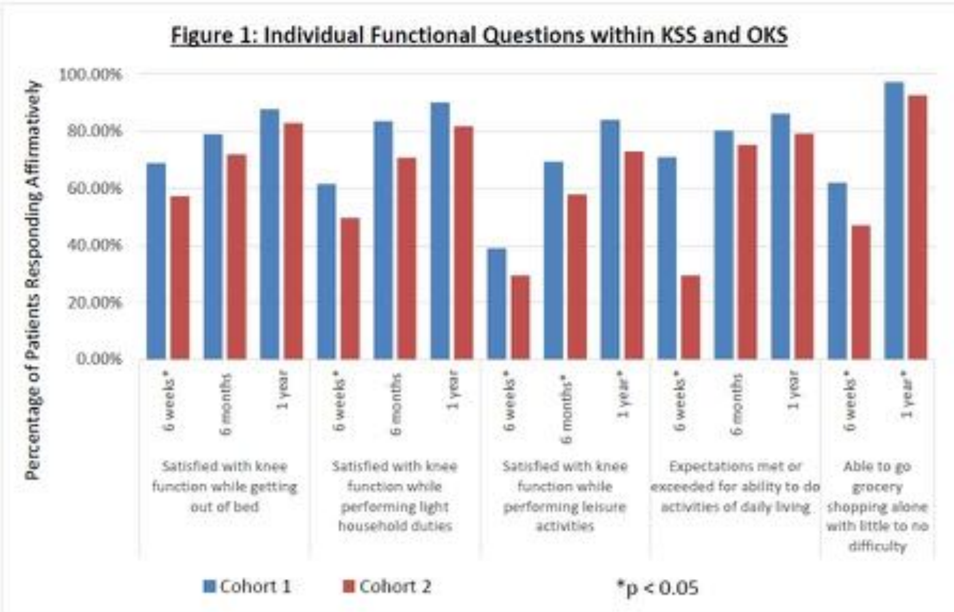

Figure 2

The Effect of Coating Thickness and Morphology on the Primary Fixation of a Femoral TKA Component

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Introduction

Although cementless press-fit femoral total knee arthroplasty (TKA) components are routinely used in clinical practice, the effect of the interference fit on primary stability is still not well understood. Intuitively, one would expect that a thicker coating and a higher surface roughness lead to a superior fixation. However, during implant insertion, a thicker coating can introduce more damage to the underlying bone, which could adversely influence the primary fixation. Therefore, in the current study, the effect of coating thickness and roughness on primary stability was investigated by measuring the micromotions at the bone-implant interface with experimental testing.

Methods

A previous experimental set-up was used to test 6 pairs of human cadaveric femurs (47-60 years, 5 females) implanted with two femoral component designs with either the standard e.motion (Total Knee System, B. Braun, Germany) interference fit of 350 µm (right femurs) or a novel, thicker interference fit of 700 µm (left femurs). The specimens were placed in a MTS machine (Figure 1) and subjected to the peak loads of normal gait (1960N) and squat (1935N), based on the Orthoload dataset for Average 75.

Varus/valgus moments were incorporated by applying the loads at an offset relative to the center of the implants, leading to a physiological mediolateral load distribution. Under these loads, micromotions at the implant-bone interface were measured using Digital Image Correlation (DIC) at different regions of interest (ROIs – Figure 1). In addition, DIC was used to measure opening and closing of the implant-bone interface in the same ROIs.

Results

After comparing the micromotions and opening of the two implant designs, we found no significant differences between the standard and novel coating. Loading was a significant factor for both opening ($P<0.0001$) and micromotions ($P=0.019$), where the squat produced higher micromotions than gait. Opening was seen anteriorly (MA, LA), and was higher during squat. Closing was noticed distally (MD, LD), particularly during gait (Figure 2).

During gait (Figure 3), the highest micromotions were found in the posterior condyles (CM, MP), followed by the medial anterior region (MA). For squat, the largest micromotions were in the anterior flange (ANT), followed by the distal regions (LD, MD).

Discussion

In the current study, the primary stability of the same implant with two different coating thicknesses was evaluated. The results demonstrate that increasing the coating thickness does not automatically influence the primary stability of a femoral TKA component. This is likely due to abrasion and damage of the underlying trabecular during implant insertion, which also was observed in previous experiments.

The exact relation between coating thickness or interference fit and primary implant stability still remains subject to debate. Obviously, the primary implant stability is compromised when the interference fit is too low. However, the current results suggest that there is a threshold beyond which further improvement of the fixation is not possible. The exact magnitude of this threshold is unknown, and may depend on coating characteristics and bone quality, and requires further evaluation, possibly utilizing a hybrid approach of experimental and computational techniques.

Figures

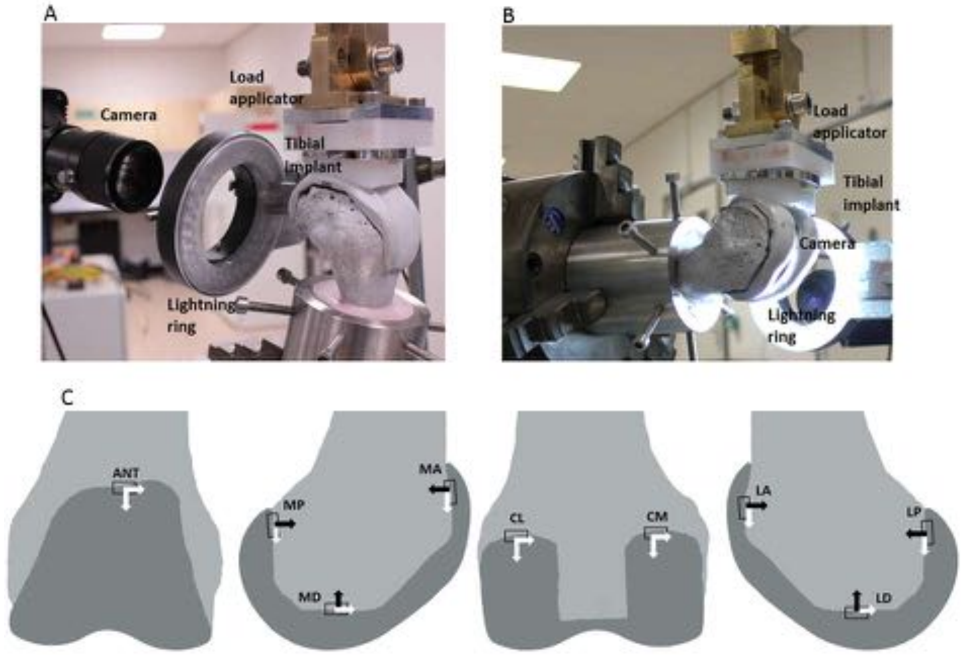

Figure 1. A) Experimental set - up for gait loading at 14°. B) Squat loading at 90°. C) The 9 Regions of interest (ROIs) for gait are defined at the bone-implant interface for the anterior flange (ANT); the anterior, distal, and posterior region of the medial (MA, MD, MP) and lateral (LA, LD, LP) views; and the medial and lateral condyles (CM, CL) For squat, the condyles are not measured, so there are 7 ROIs. Micromotions are measured as shear displacements (white arrows), while opening as normal displacement (black arrows).

Figure 1

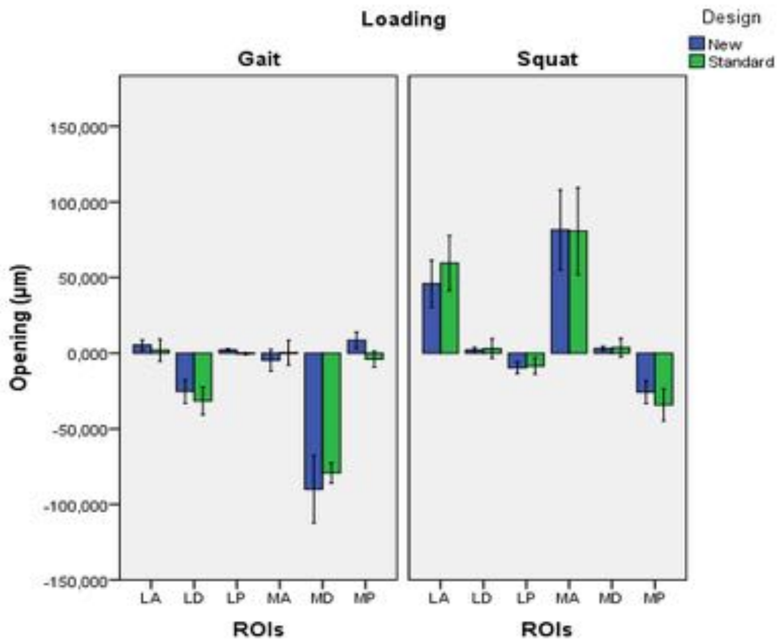

Figure 2. Estimated average opening (positive) and closing (negative) at the bone-implant interface ROIs (LA: lateral anterior; LD: latral distal; LP: lateral posterior; MA: medial anterior; MD: medial distal; MP: medial posterior) of New and Standard design with standard error of mean. The left graph represents the results under gait loading, and on the right the results under squat loading.

Figure 2

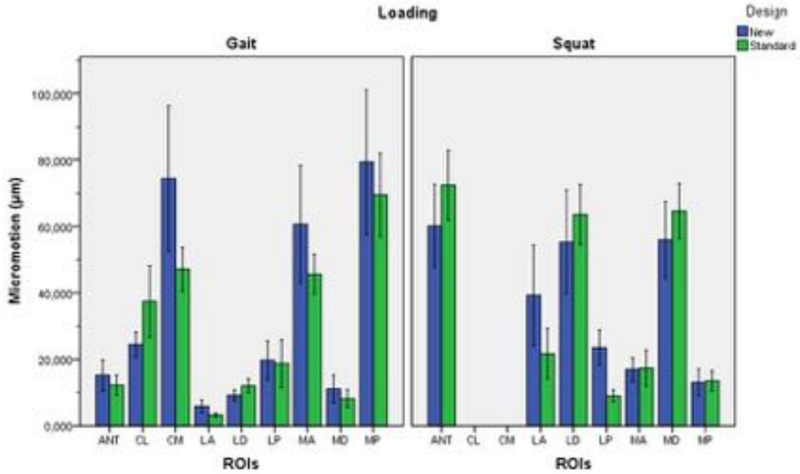

Figure 3: Estimated average micromotions at the bone-implant interface ROIs (ANT: anterior flange; CL: lateral condyle; CM: medial condyle; LA: lateral anterior; LD: latral distal; LP: lateral posterior; MA: medial anterior; MD: medial distal; MP: medial posterior) of New and Standard design with standard error of mean. The left graph represents the results under gait loading, and on the right the results under squat loading.

Figure 3

#5824

Bone Ingrowth Into EBM Implants

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Introduction

Porous integration into materials provides biological fixation at the host implant-interface. Recent developments in 3D printing provides opportunities to create novel implant architecture that may facilitate and potentially improve long-term clinical outcomes. Preclinical animal models provide a useful means to evaluate implant fixation concepts. Ideally, the more clinically relevant the model in terms of implant size and loading conditions the more it may reflect the human clinical scenario. The current study examined bone ingrowth into porous 3D printed implants in two anatomical sites.

Methods

Four skeletally mature sheep were used following ethical approval. Implants with an articular surface and 3D ingrowth backing structure were placed in the medial condyle of each femur (see figure 1), these were created using EBM in titanium or CoCr alloys. Additionally, 3D printed ingrowth dowels were placed in the proximal cancellous bone of each tibia (1 each). Animals were euthanized at 4 weeks for radiographs and PMMA histology.

Results

Surgery was well tolerated and animals were load-bearing following recovery from anaesthesia. . Harvest at four weeks was uneventful with no evidence of infection or adverse reactions. The femoral condyle implants were well fixed with no evidence of loosening at the four weeks. New bone integration at the host margins of the 3D printed structures was found in the cancellous implantation sites as well as the femoral condyle sites. Histology and thin slice radiographs in the sagittal plane revealed evidence of bone integration in the femoral condyle sites (figure 2).

Discussion

Implantation site, mechanical loading and implant architecture play a role in biological fixation. The current study examined bone integration in cortical sites, cancellous sites and in intra-articular settings. Bony integration did not appear to be dependent upon the type of metal. New bone integration into the porous domains was found in 3D printed titanium and cobalt chrome. The femoral condyle implantation site provided a loaded anatomical site which may more closely resemble the biomechanical and surgical environment of knee arthroplasty.

Figures

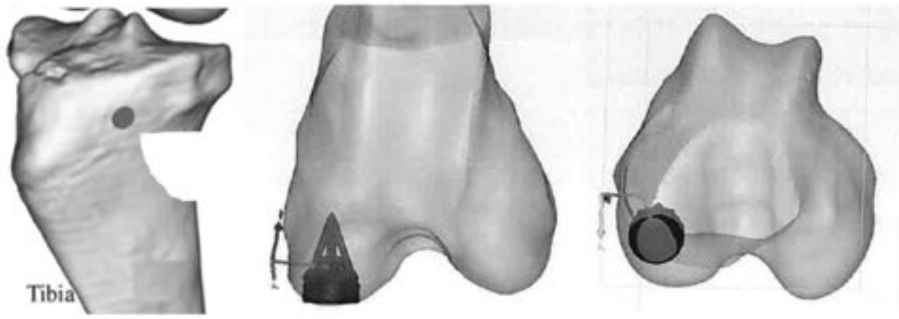

Figure 1: Implantation sites for the right and left: Cancellous bone of the proximal tibia and the medial femoral condyle.

Figure 1

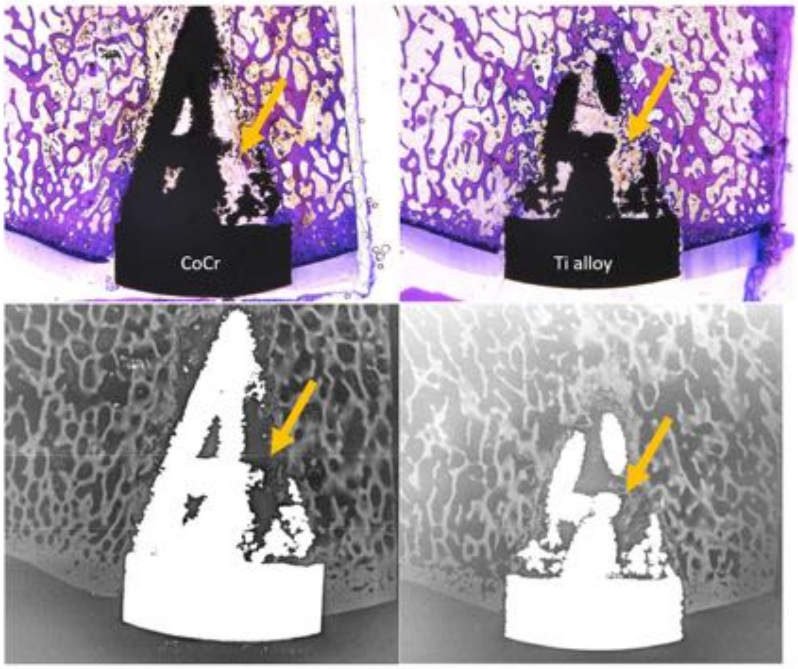

Figure 2: Example of PMMA histology and thin slice radiograph at 4 weeks for EBM printed CoCr and Ti alloy samples. New bone integration was noted into the porous domains of both materials (yellow arrows).

Figure 2

#5823

The ENGAGE Locking Knee Implant: A TKR System for Use as an Alternative to Knee Arthrodesis

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Background: Clinical and anatomical complications from total knee replacement (TKR) procedures are debilitating, and include weakness, damage, and the loss of native anatomy. As the annual number of primary TKR surgeries in the United States has continued to rise, to a projected 3.48 million in 2030, there has been a concomitant rise in revision surgery. Damage to or loss of native knee anatomy as a result of TKR revision can leave the patient with irreversible knee dysfunction, which is a contra-indication for most TKR systems on the market[1]. This leaves the multi-revision patient with limited medical options. Complete fusion of the joint, known as arthrodesis (figure 1), is indicated in some cases. Arthrodesis is also commonly indicated for traumatic injury, bone loss, quadriceps extensor mechanism damage, and osteosarcoma. While this treatment may resolve pain and allow a patient to walk, the inability to flex the knee results in considerable functional complications. Patients with arthrodesis are unable to drive, sit in close-quarter spaces, or engage in a significant number of activities of daily living.

Product Statement: The authors have developed and patented the Engage Knee System (figure 2), a novel TKR system that allows a patient to lock and unlock the knee joint by means of a handheld, non-invasive device. An internal locking mechanism is constructed of materials that have been used in orthopedic joint replacements that have been approved through the FDA 510(k) process. A lightweight, handheld magnetic device is used to actuate the locking mechanism. No percutaneous components are required or present. This device allows a patient to lock their knee joint in full extension to ambulate with the functional equivalence of an arthrodesis, but allows a patient to unlock the device and bend the knee to engage in passive activities that would be otherwise difficult or impossible. The IP portfolio for this technology is owned by Clemson University[2], and they are seeking a partner/licensee to pursue further technology development and validation.

Methods: A literature review of knee arthrodesis incidence and prevalence has been published by the inventors[3]. Three-dimensional gait analysis was used to characterize rigid-knee gait kinematics and kinetics to verify potential implant design loads[4]. Multiple physical prototypes of the design were created and implanted in Sawbones synthetic knee models, and a final prototype using industry-standard arthroplasty materials was contract-manufactured.

Results: The Engage system is capable of locking and unlocking in full extension with the use of a non-invasive hand-held device. The device will support the loading patterns and magnitudes during stiff knee gait, as estimated through gait analysis and musculoskeletal modeling, when it is locked in full extension.

Conclusion: The Engage Knee System bridges the gulf between existing treatments, and addresses not only patients who would otherwise undergo arthrodesis, but also patients who have avoided treatment or who currently undergo high-risk revision procedures. The device is also a viable option for arthrodesis takedown, providing patients who have already undergone arthrodesis a means of regaining knee flexion.

References: 1) Knutson et al. CORR 1984, 2) Lucas et al.US20140025174,

US9393123, US9693867, 3) Lucas et al. SpringerPlus 2016, 4) Lucas et al. ORS 2014.

#5946

Concept of a New Approach to Support Total Hip Replacement Procedures by Surgical Navigation

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Total hip replacement procedures are among the most frequent surgical interventions in all industrialized countries. Although it is a routine operationliterature reports that important parameters regarding for example cup orientation and leg length discrepancy often turn out to be not satisfying after surgery. This paper presents a novel concept to improve the reproducibility and accuracy for implantation of cup and stem prosthesis at exactly the desired locations. Existing computer-based commercial products either offer software solutions for just pre-operative planning, or imageless navigation systems that are only used during surgery in the operating theatre. The innovation of our approach is based on an integrated computer-assisted solution that combines pre-operative planning and intra-operative navigation to support THR procedures.

The software for pre-operative planning can process both, 3D CT images and standard 2D x-ray images. A custom-built navigation system using optical 3D localizing technology has been developed to transfer planning results to the OR. The main objective of our approach is to implant the artificial joint in a way to restore the natural anatomy of the joint before surgery as close as possible, or with exactly planned modifications. In particular, cup inclination, cumulative anteversion of cup and stem, CCD angle and lateral offset, centre of rotation, leg length discrepancy, and joint range of motion are considered. It is not necessary to determine numerical values for all of these parameters because our approach uses a unique procedure to record the natural anatomical situation by combining pre-operative planning and intra-operative navigation, and subsequently supports implantation of the prosthesis components by surgical navigation in order to restore this situation.

In case planar 2D x-ray images are used for pre-operative planning accurate scaling of these images is a prerequisite for exact determination of relevant parameters. The patient-specific scaling factor depends on the distance of the hip joint rotation centre from the x-ray detector or film. We have designed a low-cost localization system to be mounted close to the x-ray apparatus. It localizes the 3D position of the rotation centre by small motions of the leg and eliminates uncertainties of conventional methods that are caused by improper positioning of a calibration body.

Easy and robust setup and application have been key objectives for the development of our custom-built navigation system. Acquisition of intraoperative parameters for example includes the determination of the acetabular centre axis by localizing selected landmarks at the acetabular rim. Intra-operative parameters are combined with pre-operative parameters without needing sophisticated matching procedures with the pre-operative images.

A preliminary surgical workflow that will be detailed in the conference presentation has been designed for evaluation of the concept using sawbones models. Based on the promising results of our laboratory tests we have started to prepare first clinical experiments in close cooperation with surgeons.

#5861

Image Guided Surgery (Or Navigation) Software Optimization

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Many navigation (Image Guided Surgery or IGS) systems are keyed to safely and accurately placing implants into complex anatomy. In spine surgery such as disc arthroplasty and fusion surgery this can be extremely helpful. Likewise, in joint arthroplasty the accurate placement with respect to the operative plan is widely recognized to be of benefit to long term results.

However, where realignment of anatomy is desired following implant placement, such as in high tibial osteotomy, spinal fusion with correction of deformity, and spinal disc arthroplasty, navigation systems can tell you where you are, but not where you would like to be.

We have developed specific software modification technology, applicable to all current navigation systems that addresses this need for assistance in surgical correction of anatomy to a desired alignment without the requirement for further imaging or irradiation. The benefits of our software allow image free re-referencing of image guided surgery, accommodation of intra-operative changes in anatomy, and intra-operative accountability and adjustment to allow errors of image guidance to be identifiable and correctible, at any stage of image guided surgery.

This software allows accurate pre-operative planning, intra-operative verification and assessment of the operative plan, and actual outcomes of the surgery to be assessed as the surgery is performed. It allows the surgeon to subsequently verify if the operative planning has been adequately achieved, and if not can verify if continued surgery has then achieved the planning goals. This verification and image guidance does not require further imaging during surgery, relying upon the original data set and software enhancements.

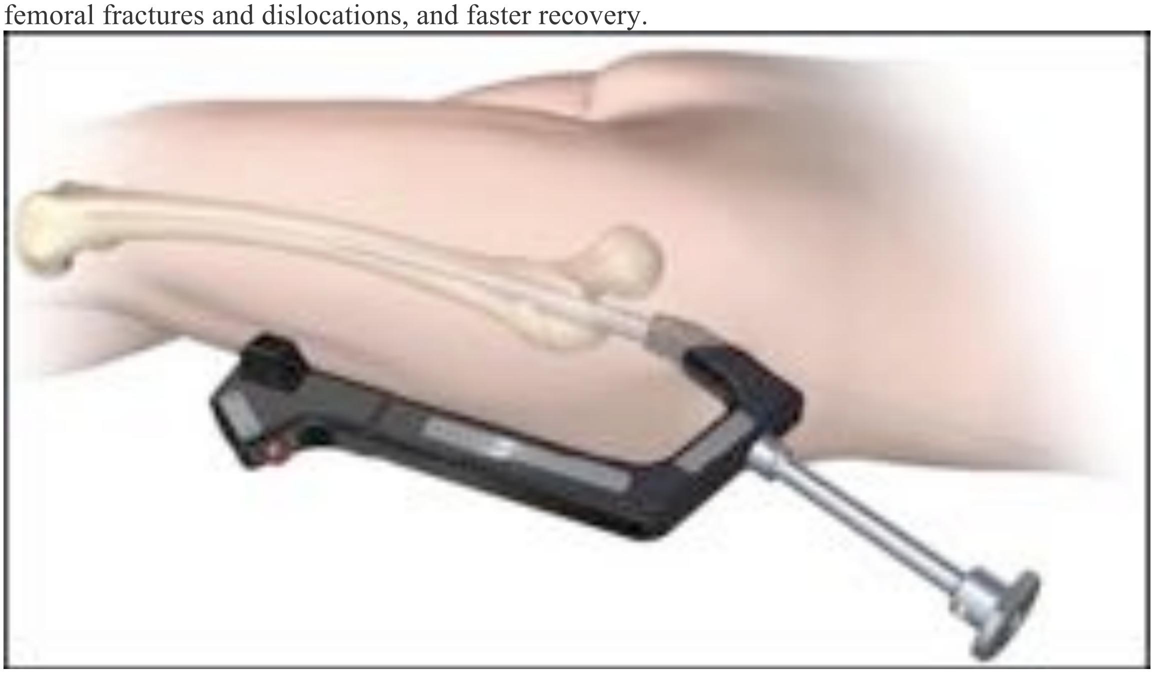
iHip Surgical innovative total hip arthroplasty proposal

Problem 1: **The direct anterior total hip arthroplasty** (DAA) was popularized by Dr. Matta, who claimed superiority of this approach in regard to reduced dislocation rate, preserving the short external rotator muscles, faster recovery, less complications. However, many studies showed **similar dislocation rates between posterior and anterior approach, longer operative time, higher blood loss, early femoral loosening and a set of unique complications including femoral fractures and nerve damage**. The biggest challenge of DAA is inserting a femoral stem in the collinear fashion between the stem and the femur.

Problem 2: **Dual taper modular-neck total hip arthroplasty** (THA) design with additional neck-stem modularity has the potential to optimize hip biomechanical parameters by facilitating adjustments of leg length, femoral neck version and offset but there is **increasing concern regarding this stem design as a result of the growing numbers of adverse local tissue reactions due to fretting and corrosion at the neck-stem taper junction**. Factors such as taper cone angle, taper surface roughness, taper contact area, modular neck taper metallurgy, femoral head size and angle of insertion play important roles in influencing extent of taper corrosion (MACC).

Solution: Improvement in modular connection may allow for safer and longer lasting THA implants, along with improvement of technical ease of implantation. The idea of our implant was "borrowed" from well-established Gamma Nail procedure for IT fractures but applied to the total hip arthroplasty.

To resolve the problem of technical difficulty of femoral stem insertion, iHip Surgical patented the following surgical technique: inserting a much slimmer stem through a small posterior-superior incision behind hip abductors allows a collinear insertion of a longer stem femoral component, no short external rotators release, faster surgery, reduced complications of femoral fractures and dislocations, and faster recovery.



The usual dual taper femoral neck has shown high rate of fretting and MACC. **iHip Surgical patented an implant design** where the Morse taper extends into a cylindrical screw to propel the neck into a female femoral stem taper in a precise collinear fashion **guaranteeing alignment and required engagement force** reducing fretting and improving longevity of the implant.

The Direct Anterior Approach is a Risk Factor for Early Failure in Cementless Total Hip Arthroplasty: A Multi - Center Study
R. Michael Meneghini , MD, J Bone Joint Surg Am. 2017 Jan 18;99(2):99-105. doi:

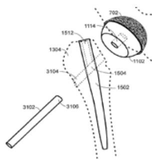
10.2106/JBJS.16.00060.:

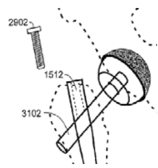
Conclusions:
"Despite claims of early recovery and improved outcomes with the direct anterior approach, our findings indicate the DAA likely confers greater risk for early ***femoral failure*** and, along with the posterior approach, a greater risk of ***early instability*** compared to the direct lateral approach following THA."

Patent portfolio:

Confidential
Work Product / Attorney-Client Privileged
Updated June 2015

Legend
ISSUED
PENDING
PCT
PROVISIONAL
~~ABANDONED~~


Neck bore access


Joining head and neck after advancing

App.: PCT/US2006/046795
FD: Dec. 7, 2006
Pub.: WO 2008/069800
PD: June 12, 2008
Status: Expired
MWE Case: 093715-0011

App.: 12/518,081
FD: June 5, 2009
Pat.: 8029573
ID: Oct. 4, 2011
MWE Case: 093715-0016

DIV

App.: 13/049,619
FD: March 16, 2011
Pat.: 8211183
ID: July 3, 2012
MWE Case: 093715-0017

CON

App.: 13/471,137
FD: May 14, 2012
Pat.: 8795381
PD: Sep. 6, 2012
MWE Case: 093715-0020

CON

App.: 14/452,404
FD: Aug. 5, 2014
Pub.: 2014-0350690
PD: Nov. 27, 2014
Status: Published
MWE Case: 093715-0034

EP App.: 06839183.8
FD: July 2, 2009
Pub.: 2094197
PD: Sep. 2, 2009
Status: Published
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Extension

HK App.: 10100817.9
FD: Jan. 26, 2010
Pub.: 1133573
PD: April 1, 2010
Status: Published
MWE Case: 093715-0015

AU App.: 2006351469
FD: June 10, 2009
Pat.: 2006351469
ID: Jan. 31, 2013
MWE Case: 093715-0012

CA App.: 2,671,523
FD: June 3, 2009
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ID: Feb. 12, 2013
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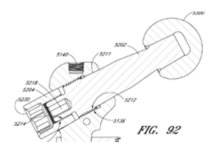

Taper and thread in bore

CIP

App.: 13/335,216
FD: Dec. 22, 2011
Pat.: 8579985
ID: Nov 12, 2013
MWE Case: 093715-0018

CON

App.: 14/077,054
FD: Nov. 11, 2013
Status: Published
MWE Case: 093715-0026

App.: PCT/US2012/024161
FD: Feb. 7, 2012
Pub.: WO 2013/095687
PD: June 27, 2013
Status: Expired
MWE Case: 093715-0019

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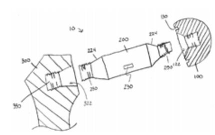
Status: Published

CA App.: 2859745
Status: Published

CN App.: 201280070370
Status: Published

AU App.: 2012355962
Status: Published


Dual tapers and threads

CIP

Prov. App.: 61/722,960
FD: Nov. 6, 2012
Status: Pending
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App.: 13/797,794
FD: Mar. 12, 2013
Pat.: 8974540
PD: Mar. 10, 2015
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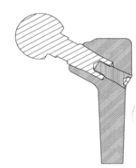
Monoblock / Opposing tapers

App.: PCT/US2013/068816
FD: Nov 6, 2013
Status: Expired
MWE Case: 093715-0025

CIP

App.: 14/073,796
FD: Nov 6, 2013
Pub.: 2014/0128986
PD: May 8, 2014
Status: Published
MWE Case: 093715-0023

#6125

A Trial Femoral Head for Intraoperative Evaluation of Combined Anteversion

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[Introduction] To control anteversion of the acetabular cup and femoral stem within an appropriate angle range is extremely important in total hip arthroplasty. The sum of these angles is called the “combined anteversion” (CA), and a navigation system is necessary for its accurate intraoperative evaluation. However, navigation is too expensive and time-consuming to be commonly used. Therefore, a cheaper and easier tool for intraoperative CA evaluation is desired in the clinical field. I had an idea of marking ruler-like scales on a trial femoral head ball for this purpose. The purpose of this study was to introduce the idea in a computer simulation.[Materials and Methods] An acetabular cup, a femoral head, and a femoral stem were designed virtually using three-dimensional computer graphics software (FreeCAD). The head was assembled with the femoral stem, and the axis of the stem was tilted 7 degrees to the vertical axis, referring the angle between mechanical and anatomical axes of the femur. Ruler-like scales and a horizontal line were marked on the surface of the head. The cup inclination angle was fixed at 40 degrees and paired with the head and stem assembly. The cup axis was on the stem–neck plane, which meant that CA was zero before rotating the cup and the stem. The scale at an intersecting point of the inner edge of the cup and the horizontal line was read before and after rotating the cup and the stem. I confirmed if the sum of the rotated angles of the cup and stem and the angle indicated by the scales were consistent when they were rotated at an arbitrary angle.[Results] CA was successfully evaluated by the difference in angle indicated by the scales before and after rotation.[Discussion] There are several definitions for cup and stem anteversion. The CA evaluated in this study was the sum of anatomical anteversion of the cup and the angle between the neck axis and epicondylar or posterior-condylar axes of the knee projected on the horizontal plane. There are several factors that make the CA evaluation by this method inaccurate. For example, when the cup inclination angle is not 40 degrees, or the pelvis or the femur are not held at the intended position, the CA indicated by the scales is not accurate. It is my future work to assess whether this method is accurate enough to be used in the clinical situation.[Conclusion] Marking ruler-like scales on the femoral head would be a low-cost and effective method for rough intraoperative evaluation of CA.

#5859

Fiducial Surgical Navigation Screw

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Image guided surgery (IGS), or “Navigation,” is now widely used in many areas of surgery including arthroplasty. However, the options for establishing, in real time, the veracity of the navigation information are limited. Manufacturers recommend registering with a “prominent anatomical feature” to confirm accurate navigation is being presented. In their fine print, they warrant the accuracy proximate to the navigation array attached to the body. In multi-level spine surgery where it is most sorely needed, this limits the warrants to the vertebra of reference array attachment. In arthroplasty surgery, the accuracy of the system can be erroneous through technical errors and a delay may occur prior to verification of such innacuracy.

In response to this situation surgeons have taken to using K-wires, FaxMax screws and a variety of other “Fiducial Markers”, but these were not specifically designed for this purpose and in many ways are inadequate for the task of verification of navigation accuracy.

We have developed a fiducial marker that is designed to address these unmet needs. The Precision Screw is clearly visible on imaging modalities and the central registration point is identifiable at any angle of viewing, with accuracy of fractions of a millimeter. It does not interfere with surgery, being low profile and securely fixed to bone. Finally, in use, it is secure in capturing the navigation probe so that the surgeon does not need to focus on keeping the probe located while reviewing the navigation data.

We believe these features make this a useful and worthwhile addition to IGS.

#5572

Antimicrobial Dispensing Knee Spacer for Improved PJI Treatment

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Worldwide estimates for 2017 indicate orthopedic physicians will identify 74,000 patients with Periprosthetic Joint Infection (PJI) in total knee joints requiring treatment. Current infection treatment options are poor: all are surgical; all have limited average success rates (≤ 90% successful); and all are costly procedures. If the infection is not eradicated from the first treatment, the patient undergoes additional procedures to forestall sepsis. When PJI persists, patients suffer high morbidity due to repeated procedures, bone loss, an increasing risk for amputation and potentially death.

Through physician interviews, we have identified critical contributors to poor infection eradication rates and a primary factor is <u>insufficient therapeutic levels of antibiotic in the knee's synovial fluid during treatment</u>. The current standard of care treatment involves surgical debridement and implant replacement concurrent with systemic antibiotics. Yet, studies of systemic antibiotics indicate poor antibiotic transfer into the knee synovial fluid with minimal therapeutic benefits.

Orthopedic surgeons performing 2-Stage revisions attempt localized antibiotic treatment using antibiotic impregnated cement formed into temporary spacers placed in the joint at the time of surgery along with bio-absorbing antibiotic beads. These temporary spacers are removed in a 2nd surgery after treatment, when monitored infection biomarkers in the blood are depleted. During this treatment period, ranging from 8 weeks to 6 months with static antibiotic spacers *in situ*, the patient's knee is non-functioning. Published studies indicate that with antibiotic impregnated cement, elution rates drop precipitously over just a few days resulting in minimal antibiotic concentration in the synovial fluid after a week. Elution rates from antibiotic beads drop below therapeutic levels within 30 days. Neither antibiotic dosing is long enough to support effective therapy and neither can be replenished during treatment without additional surgery.

Conceived by Dr. Jared Foran, an orthopedic surgeon and co-founder of ForCast Orthopedics, the ACE Knee Spacer incorporates a refillable antibiotic reservoir combined with a daily dosing system to assure sufficient and consistent therapeutic levels of antibiotic in the knee. The hollow knee spacer is filled with the physician's liquid antibiotic of choice which then doses the synovial fluid at a prescribe amount to maintain therapeutic concentrations. The reservoir is refilled periodically through a percutaneous injection. Through improved eradication rates, the ACE Knee Spacer will improve patient outcomes, and represent a significant healthcare cost savings by reducing the use of ineffective systemic antibiotic treatment.

The premise for success of the ACE Knee Spacer is drawn from published clinical research using implanted catheters for daily antibiotic injections in the knee which resulted in superior eradication rates. However, adoption of this research treatment has been limited due to the burden of daily office-based injections and patient management of an exposed sterile catheter for multiple weeks. The ACE knee spacer 1) duplicates this successful antibiotic administration method for better patient outcomes but 2) employs a less burdensome approach using weekly, percutaneous refill/check-up appointments, and 3) eliminates patient-catheter management burdens.

ForCast Orthopedics is currently raising a Seed round of funding to pursue additional development and testing to demonstrate the device’s capabilities.

#5494

How Can an Electronic Tool Improve the Results After TKA? Comparing the Results Including 1 Year FU

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Christoph Stiegler - MIT Entwicklungsges.m.b.H. - Kapfenberg, Austria

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Introduction

Sensoric soft tissue balancing in performing TKA is an upcoming topic to improve the results in TKA. A well balanced knee is working more proper together with the muscular stabilizing structures.

Dynamic ligament balancing (DLB)^R give us the opportunity to check the balance of the ligaments at the beginning and the end of the surgery before implanting the definitive prosthesis. It is a platform independent, single-use device, which can be combined with all common types of knee prosthesis.

Materials and Methods

DLB^R consists of a set of 10 different sizes of baseplates including a spring coil of 20N (A). Connected to a tablet all datas can be shown during surgery and stored for patient security. During the surgery the tibial cut is performed first, rectangular to the longitudinal axis respecting the right slope. A navigation system is recommended to ensure this request. Measurement before femoral cuts are performed and give an information about distance between tibial plate and femoral condyles, joint angle and calculated contact pressure. The femoral cuts can be performed with the original cutting block.

After positioning the femoral trial, testing is repeated and should show a balanced situation over all the ROM. The overall period datas were stored and compared to the subjective feeling of the patients.

Results

Performing the first 20 patients (DLB) a better balanced situation is visible in all knees respecting the including factors in comparison to the 20 patients of control group (CG). No extension of the surgical time was seen. All PROMs show good and excellent results. By example there was an improvement of the result of the OKS at the end of 10% by a much worse initial situation; so the overall progress was in the CG about 50%, in the DLB group 150%. The AKSS shows especially in the functional score a similar improvement (Fig. 1-4)

Discussion

DLB^R is a new concept using single-use devices and is platform independant. Further measurements and comparisons are necessary to value these first excellent results. By the moment the inclusion factors are settled narrow, but the future will show, where the borders of this method will be.

Conclusion

Measuring the gap and ligament tension all over the ROM from 0 to 90° continuously gives the possibility to value the accuracy of the procedure together with marking points to compare it to the clinical postoperative result. Matching the procedure shows an increasing satisfaction of the patients due to a better balanced situation. Although there are limiting factors (no severe deformities, muscular deseases, ligament failure) it is a hopeful opportunity to increase the results in TKA in the future.

A) Loads balancing in total knee arthroplasty: What loads are present in the native knee

Verstraete M., Meere Patrick A., Salavadore G., Victor J., Walker P.S. , ISTA 2016 Boston

Figures

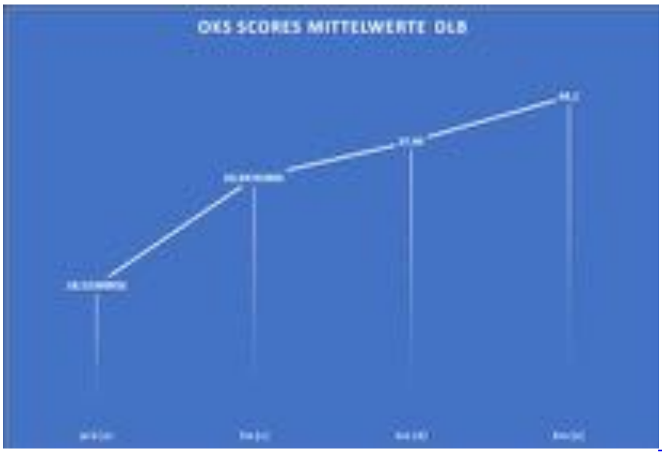

Figure 1

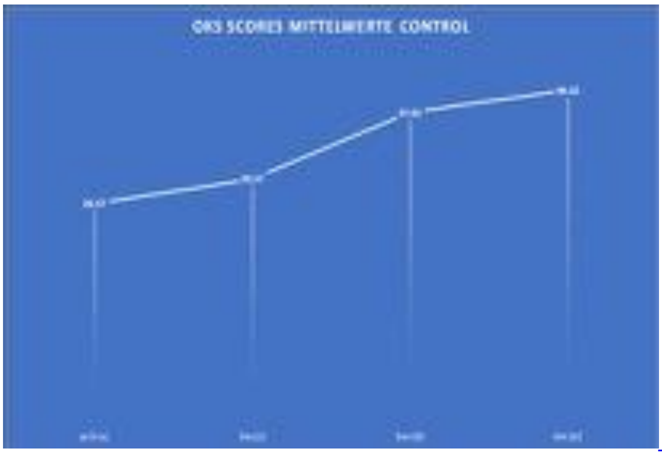

Figure 2

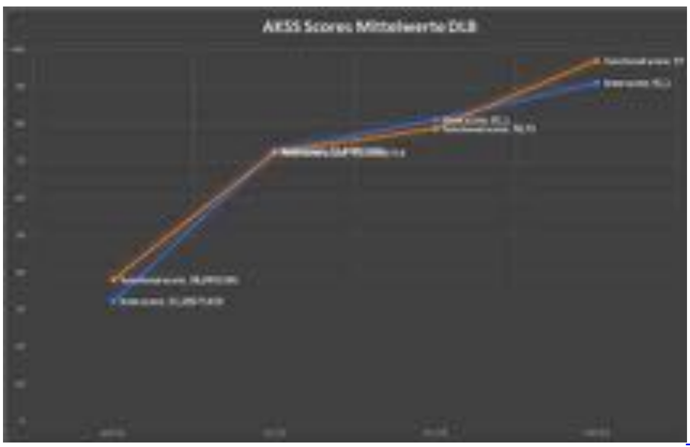

Figure 3

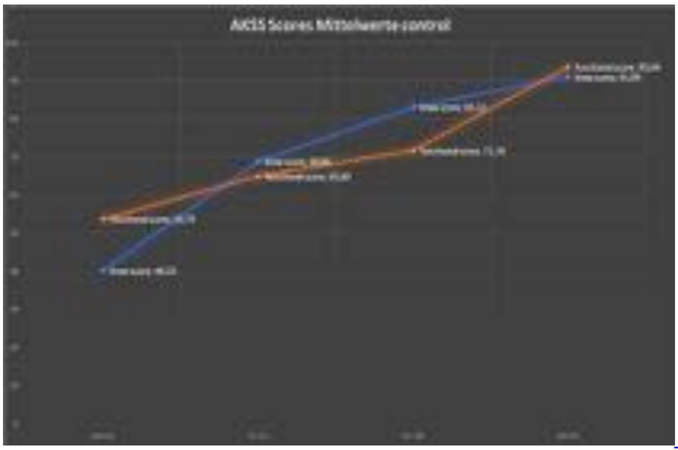

Figure 4

#5887

A Novel Guide for Locating Femoral Head Center in Knee Surgeries

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Purpose: The lower limb alignment is important in knee surgeries, and the alignment is defined using the centers of hip, knee and ankle joints. Traditionally, young physicians are taught that the center of femoral head (COFH) is approximately one inch medial and inferior to the anterior superior iliac spine (ASIS). However, the distance varies among different individuals. Moreover, the length of incision in knee surgeries has been reduced in last few decades making the joint alignment a challenging task. There are two major approaches for precise location of COFH during knee surgeries such as TKR and osteotomies. One of them uses intraoperative x-ray and the other uses latest technologies such as navigation system or accelerometer based device. The x-ray approach has issues related to radiation hazard and machine availability on time. The latest technologies are expensive and need significant amount of time to set up. However, a mechanical device can be used to produce a modestly precise alignment of the knee. This work presents a novel mechanical device which is combined with long leg x-ray information to assist in checking the knee alignment during surgery.
Method:
COFH position: The COFH is located in a long leg x-ray film of the patient and its distance from the pubic symphysis is recorded in millimeter. A customized adjustable mechanical frame (Figure 1) for pelvis is positioned so that the cups in the frame fit firmly on two ASIS. A projection of the location of pubic symphysis on the ruler of the frame is located as the center of the frame. The COFH's projection on the ruler is marked using the distance measured on long leg x-ray after correction with magnification rate.
During the surgery, if the knee alignment needs to be examined, the leg is straightened with the ankle and knee pointing towards ceiling and the mechanical frame's cups are made to fit both ASIS. A long metal rod with a sliding perpendicular pin is made to be positioned above the leg, so that the proximal end of the rod sits on the COFH's projected point, and the distal end sits at the midpoint of the anterior aspect of the ankle. If the mechanical alignment is good, the rod would be aligned to the midline of the knee joint and the anterior tibial baseplate should be perpendicular to the rod. If kinematic alignment is the goal, the medio-lateral slope of the tibial tray can be checked and corrected according to preoperative planning.
Conclusion: We present a knee alignment checking device for knee surgeries in which proper alignment matter. The device was designed to duplicate the effect of intraoperative x-ray method and reduce the number of outliers. The presented method takes much less time and is less expensive compared to other approaches. The method is specifically useful for obese and muscular patients when visual inspection to decide alignment may not be sufficient especially with air tourniquet tied on patient.

Figures

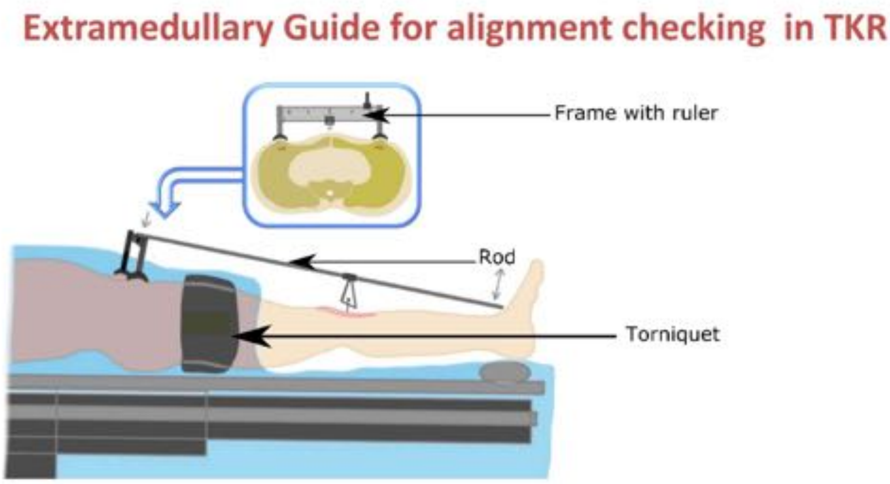

Figure 1: Extramedullary guide for alignment check

Figure 1

#6107

Higher Volume Surgeons Have Lower Cost, Readmissions, and Mortality After THA

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INTRODUCTION:

The advent of value-based care, in which surgeons and hospitals accept more responsibility for clinical and financial results, has increased the focus on surgeon- and hospital-specific outcomes. However, methods to identify high quality, low cost surgeons are not well developed. The current study seeks to determine whether there is a relationship between surgeon Total Hip Arthroplasty (THA) volume and the outcomes of mortality, readmission, and Medicare expenditure for that surgeon.

METHODS:

We performed a retrospective analysis of Centers for Medicare and Medicaid Services (CMS) Limited Data Set (LDS) on all primary elective THAs performed in the United States (except Maryland) between January 2013 and June 2016 on patients insured by Medicare. This represented 409,844 THAs totaling more than USD $7.7 billion in direct CMS expenditures. Surgeons were divided into five groups based on annualized volume of CMS elective THAs over the study period. Using regression, we calculated and compared CMS Part A payments over 90-day periods, readmissions, and mortality among the groups. Ninety-day payments and incidences of readmission and mortality were calculated and compared among the groups. For each episode, demographic information (age, sex, and race), geographic location, and Elixhauser comorbidities were calculated to control for major confounding factors in the regression.

RESULTS:

When compared to the highest volume group, each lower-volume group had increased costs, increased readmission rates, and increased mortality rates in a stepwise fashion when controlling for patient-specific variables, including Elixhauser comorbidity index, demographic information, region, and background trend (Figure 1). The lowest volume group resulted in 27.20% more CMS payments per case ($p < 0.001$; 95% confidence interval (CI), 26.62%–27.78%), had an increased mortality odds ratio (OR) of 4.69 ($p < 0.001$; 95% CI, 3.99–5.50), and had an increased readmission OR of 1.77 ($p < 0.001$; 95% CI, 1.69–1.85) when compared to the highest volume group. In terms of surgeon volume, moderate-, high- or highest-volume surgeons (11+ annual cases) performed 78.49% of THAs, and included 25.67% of operating surgeons. The low- and lowest-volume surgeons (10 or fewer annual cases) performed only 21.51% of THA in the US while representing 74.33% of unique operating surgeons.

DISCUSSION AND CONCLUSION:

There is a strong association between a surgeon's Medicare volume and lower CMS payments, mortality, and readmissions. Further, the majority of Medicare THA in the US are performed by surgeons who perform more than 10 operations in CMS insured patients annually. These results suggest a benefit to sub specialization. However, many individual exceptions exist where higher volume surgeons are higher cost and lower volume surgeons are lower cost. Therefore, although there is an association between volume and outcomes, as comprehensive CMS data is available, each individual surgeon may be assessed based on actual results instead of through association with volume alone. More research should be undertaken to determine additional surgeon and hospital factors leading to improved outcomes in THA.

Figures

Figure 1

Figure 1

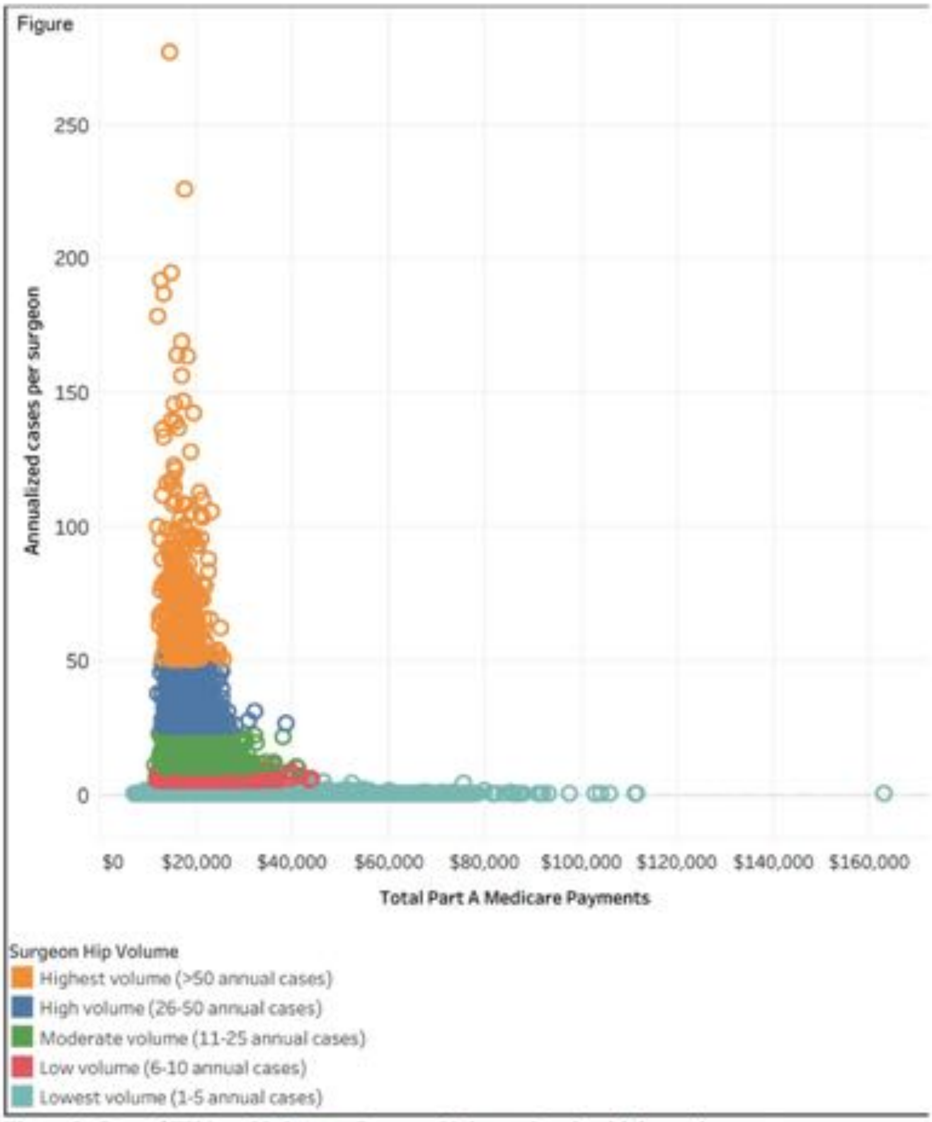

Figure 2. Cost of THA at 90 days vs Surgeon Volume showing higher volume surgeons are lower cost as a group. However many individual lower volume surgeons are associated with lower cost than many of the high volume surgeons.

Figure 2

Evidence-Based Thresholds for the Volume and Cost Relationship in Total Hip Arthroplasty: Outcomes and Economies of Scale

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BACKGROUND:

High-volume surgeons and hospital systems have been shown to deliver higher value care in several studies. However, no evidence-based volume thresholds for cost currently exist in total hip arthroplasty (THA). The objective of this study was to establish clinically meaningful thresholds in cost for surgeons and hospitals performing THA. A secondary objective was to analyze the relative market share of THAs among the newly defined surgeon and hospital volume strata.

METHODS:

Using 136,501 patients from the New York State Department of Health's SPARCS database undergoing total hip arthroplasty, we used stratum-specific likelihood ratio (SSLR) analysis of a receiver operating characteristic (ROC) curve to generate volume thresholds predictive of increased costs for both surgeons and hospitals. Additionally, we examined the relative proportion of annual THA cases performed by each of these surgeon and hospital volume strata we had established.

RESULTS:

SSLR analysis of cost by annual surgeon THA volume produced stratifications at: 0-73 (low), 74-123 (medium), and 124 or more (high) (Figure 1). Analysis by annual hospital THA volume produced stratifications at: 0-121 (low), 122-309 (medium), and 310 or more (high) (Figure 2). Hospital costs decreased significantly ($P < .05$) in progressively higher volume stratifications. The largest proportion of THA cases are performed at high-volume hospitals (48.6%); however, low-volume surgeons perform the greatest share of these cases (44.6%) (Figure 3).

CONCLUSIONS:

Our study establishes economies of scale in total hip arthroplasty by demonstrating a direct relationship between volume and cost reduction. High-volume hospitals are performing the greatest proportion of total hip arthroplasties; however, low-volume, surgeons perform the largest share of these cases, which highlights a potential area for enhanced value in the care of patients undergoing total hip arthroplasty.

Figures

Figure 1. Surgeon threshold analysis.

Volume	SSLR	Category	*P* values	No.	Odds ratio
0	1	Low	0.010	3813	4.828 (2.374-9.820)
1	1.10				
2	1.21				
3	1.30				
5	1.42				
10	1.60				
25	2.31				
50	2.48				
74	2.95	Medium	0.013	256	1.968 (0.820-4.727)
80	2.96				
95	2.99				
102	3.17				
112	3.13				
125	4.38	High		261	Reference
139	4.70				
140	4.26				
150	3.78				

SSLR, stratum specific likelihood ratio. Low: $19,524.37, Medium: $19,434.30, High: $19,000.33.

*When sampling is low, sensitivity and 1 − specificity are low and thus may cause SSLR to decrease within a grouping as observed with the above volumes at 140 and 150.

Figure 1

Figure 2. Hospital threshold analysis.

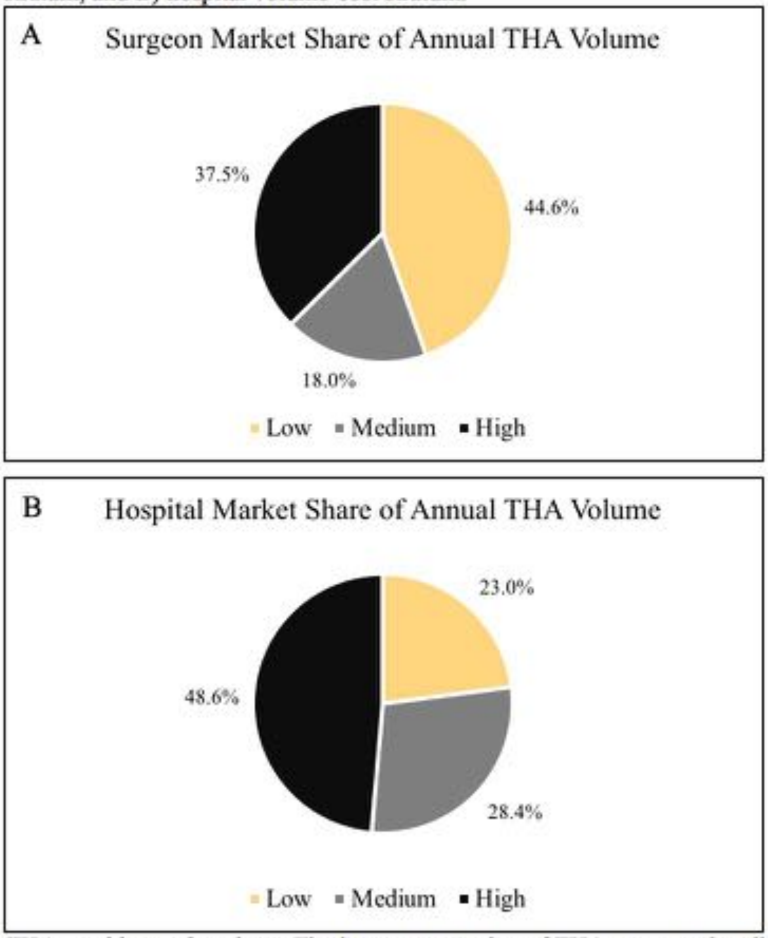
Volume	SSLR	Category	*P* values	No.	Odds ratio
0	1	Low	0.010	837	13.387 (1.843-97.215)
1	1.00				
2	1.03				
3	1.08				
5	1.16				
10	1.25				
25	1.55				
50	1.96				
75	2.55				
100	2.87				
122	4.19	Medium	<0.001	228	3.165 (0.398-25.169)
150	4.78				
200	3.52				
250	3.30				
298	5.06				
310	12.35	High		70	Reference
320	11.46				
348	10.71				
362	10.12				

SSLR, stratum specific likelihood ratio. Low: $21,044.92, Medium: $20,285.48, High: $17,924.48.

*When sampling is low, sensitivity and 1 − specificity are low and thus may cause SSLR to decrease within a grouping as observed with the above volumes at 320, 348, and 362.

Figure 2

Figure 3. Market share analysis of annual THA caseload among A) surgeon volume-cost stratum, and B) hospital volume-cost stratum.



THA, total hip arthroplasty. The largest proportion of THA cases are handled by low-volume surgeons (44.6%) and at high-volume hospitals (47.6%).

Figure 3

#6106

Analysis of US Hip Replacement Bundled Payments: Physician-Initiated Episodes Outperform Hospital-Initiated Episodes

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INTRODUCTION:

The Centers for Medicare and Medicaid Services (CMS) launched the Bundled Payment for Care Improvement (BPCI) Initiative in 2013 to create incentives to improve outcomes and reduce costs in various clinical settings, including total hip arthroplasty (THA). This study seeks to quantify BPCI initiative outcomes for THA and to determine the optimal party (e.g. Hospital vs Physician Group Practice [PGP]) to manage the program by comparing 90-day payments, readmissions, and mortality.

METHODS: We performed a retrospective analysis on the CMS Limited Data Set (LDS) on all Medicare primary elective THAs without major comorbidity performed in the United States (except Maryland) between January 2013 and March 2016, totaling more than $7.1 billion in expenditures. Episodes were grouped into hospital-run BPCI (n = 42,922), PGP-run BPCI (n = 44,662), and THA performed outside of BPCI (n = 284,002). All Medicare Part A payments were calculated over a 90-day period after surgery and adjusted for inflation and regional variation. For each episode, age, sex, race, geographic location, background trend, and Elixhauser comorbidities were determined to control for major confounding variables. Total payments, readmissions, and mortality were compared among the groups with logistic regression.

RESULTS: When controlling for demographics, background trend, geographic variation, and total Elixhauser comorbidities in elective DRG 470 THA episodes, BPCI was associated with a 4.44% (95% CI, -4.58% to -4.30%; $p < 0.001$) payment decrease for all participants ($1,244 decrease from baseline of $18,802); additionally, odds ratios (ORs) for 90-day mortality and readmissions were unchanged. PGP groups showed a 4.81% decrease in payments (95% CI, -5.01% to -4.61%; $p < 0.001$) after enrolling in BPCI ($1,335 decrease from baseline of $17,841). Hospital groups showed a 4.04% decrease in payments (95% CI, -4.24% to 3.84%; $p < 0.01$) after enrolling in BPCI ($1,138 decrease from baseline of $19,799). The decrease in payments of PGP-run episodes was greater compared to hospital-run episodes. ORs for 90-day mortality and readmission remained unchanged after BPCI for PGP- and hospital-run BPCI programs. The average Elixhauser comorbidity index rose by 0.21 for hospital-run episodes after BPCI (95% CI, 0.03–0.38; $p = 0.02$) and by 0.19 for BPCI episodes overall (95% CI, 0.02–0.037; $p = 0.03$), while there was no change in PGP-run programs ($p = 0.21$). Patient age did not change after BPCI for PGP-run ($p = 0.97$), hospital-run ($p = 0.62$), or overall BPCI episodes ($p = 0.73$).

DISCUSSION AND CONCLUSION:

Even when controlling for decreasing costs in traditional fee-for-service care, BPCI is associated with payment reduction with no change in adverse events, and this is not due to the selection of younger patients or those with fewer comorbidities. Further, physician group practices were associated with greater payment reduction than hospital programs, with no difference in readmission or mortality from baseline for either. Physicians may be a more logical group than hospitals to manage payment reduction in future healthcare reform.

#6034

Can a Balanced TKA Save Money Post-Operatively?

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Introduction: Close to 30% of the surgical causes of readmission within 90 days post-total knee arthroplasty (TKA) and nearly half of those occurring in the first 2 years are caused by instability, arthrofibrosis, and malalignment, all of which may be addressed by improving knee balance. Furthermore, the recently launched Comprehensive Care for Joint Replacement (CJR) initiative mandates that any increase in post-acute care costs through 90-days post-discharge will come directly from the bundle payment paid to providers. Post-discharge costs, including the cost of readmissions for complications are one of the largest drivers of the 90-day cost of care. It is hypothesized that balanced knees post-TKA will lower the true provider costs within the 90-day bundle.

Methods: Cost, outcomes and resource utilization data were collected from three independent surgeons pre- and post- adoption of intraoperative technology developed to provide real-time, quantitative load data within the knee. In addition, data were collected from Medicare claims, hospital records, electronic medical records (EMR), clinical, and specialty databases. The cohorts consisted of 932 patients in the pre-adoption group and 709 patients in the post-adoption group. These 2 groups were compared to the CMS national average data from 291,201 cases. The groups were controlled for age, sex, state, and BMI with no major differences between cohorts. The cost factors considered were the length of hospital stay, physician visits and physical therapy visits in addition to post-operative complications (e.g., manipulation under anesthesia (MUA) and aseptic revision).

Results: After adoption of technology to improve ligament balancing intra-operatively, all three surgeons decreased their patients' hospital stay (3.0 days to 2.6 days), number of physician visits (2.3 to 2.1), number of outpatient physical therapy visits (14.9 to 10.6) and MUA rate (2.3% to 1.8%). These clinical benefits subsequently lowered the 90-day net cost of TKA an average of $443 per case. When compared to the national average, this cost savings was $725 per case.

Conclusions: Appropriately balancing TKA patients intra-operatively might help mitigate costs associated with TKA procedures within the 90-day bundle. In this study, it was found that using new joint balancing technology generated a substantial cost-savings post-discharge, primarily due to patients requiring less outpatient physical therapy.

#5698

Cost Saving in Total Joints: Lessons Learned

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Background: We identified several opportunities to significantly reduce cost for hip and knee arthroplasty procedures:

1. Customized instruments: by identifying the essential instruments for arthroplasty cases, we managed to have one universal tray for each case, and 3 specific trays from the implant manufacturing company.
2. Customized wrap-free, color-coded, stackable trays: by using a wrap-free trays, preparation time in central sterile, opening tray time in OR and turn-over time were reduced. Also, stackable trays were organized based on side and size, therefore only 2 trays needed to be used in each case.
3. Discounted implants: negotiated through optional case coverage with revision system and reps available as backup.
4. Optional rep coverage protocols: designed through process management of the operating room surgical staff and central sterile

Aim of the study was to measure the cost savings,efficacy,and outcomes associated with primary total hip and knee arthroplasty by implementing these protocol

Methods: This is a prospective study from January to October 2016 for selected primary total hip and knee arthroplasties were performed with the above protocols by 2 experienced arthroplasty trained surgeons, were followed for minimum 3 months. Initiating the cost saving protocols were achieved by re-engineering customized trays, discounted implants through optional case coverage (Sourced Based Selection of a Cooperating Manufacturer, MTD), and focused on process management of the staff training. Staff responsibilities were divided into 2 categories:

1. Familiarity of the instruments, implant, and techniques; trays set up and assurance of availability of the implants. These responsibilities were covered by a trained OR technician and the surgeon
2. Final verification of the accurate implants prior to opening the packaging. This was achieved by a trained OR nurse and the surgeon

Results: We did not have any intra-operative complications. We also did not encounter any issued with the trays or errors in opening of the implants. There were no re-admissions, fracture, dislocation, or infection. The mean length of stay was 2.2 ± 0.5 days (range 1-3 days) with 68% home discharges.

The cost of the implant was reduced from $4,800 to $1,895 with $2,905 cost saving per case and total savings of $58,100. The projected savings only for uncomplicated primary total hip arthroplasty (minimum 120 cases/year between 2 surgeons) is $384,600. Further cost saving from the process management changes were seen in central sterile processing time. Prior to the one tray system, the hospital had 3 in-house trays and there were 4 device company trays. We also noticed an approximate 27% improvement in turnover time.

Conclusion: Repless model has significant cost saving potential. Preparation for the transition, proper patient selection, standardization of the trays and implants, and distribution of the responsibilities between OR nurses, technicians and the surgeon are essential.

#5705

Risk Factors Associated With Manipulation Under Anesthesia After Total Knee Arthroplasty

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Introduction

Manipulation under anesthesia (MUA) after total knee arthroplasty (TKA) is used to restore range of motion. This study identifies MUA risk factors that may help initiate early interventions to improve outcomes.

Methods

Data was retrospectively reviewed in 2,925 primary TKAs from October 2013 through December 2015 from 13 orthopedic surgeons. Data was obtained from hospital and private practice electronic medical records (EMR).

Statistical analysis evaluated the MUA and non-MUA groups, comparing demographic, operative, hospital-visit, and clinical factors. T-test, chi-square test, ANOVA and regression analysis were performed. Significance was set at $p<0.05$.

Results

Of 2,925 TKAs, 208 MUAs were performed (7.1%) with no significant differences between groups in sex, BMI, or diabetes status. Mean age of the MUA group was 61.98 years old, and 66.89 years old in the non-MUA group ($p<0.005$). The ratio of patients with high cholesterol was 3.37% (7/208) in the MUA group, and 1.10% (30/2717) in the non-MUA group ($p=0.014$). The ratio of African-American patients in the MUA group was 6.73% (14/208), and 2.94% (80/2717) in the non-MUA group ($p=0.003$). Of the cases with device data recorded in the EMR (n=1890), the incidence of MUA in patients receiving a cruciate-retaining (CR) device was 14.58% (50/343), and 9.57% (148/1547) in patients receiving a posterior-stabilized (PS) device ($p=0.006$). A patient receiving a CR device is 52.35% more likely to undergo an MUA than a patient receiving a PS device (95% CI, 1.13-2.05). With the numbers available for this investigation, there were no significant differences found between groups in relation to surgeon, length of stay, discharge disposition, device manufacturer, or smoking status.

Conclusion

MUA risk factors include a lower mean age, high cholesterol, African-American, and receiving a cruciate-retaining device.

#5902

International, Multi-Centre, Prospective, Observational Study of a New Medial Ball-in-Socket Knee Replacement

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Abstract submission for ISTA 2018

International, multi-centre, prospective, observational study of a new medial ball-in-socket knee replacement

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This study was sponsored by Medacta International SA

Background

In the late 1980's Michael Freeman conceived the idea that knee replacement would most closely replicate the natural knee joint if the medial Tibio-Femoral articulation was configured as a ball-in-socket. Over the last three decades, medial rotation and medial pivot designs have proven successful in clinical use. Freeman's final iteration of the medial ball-in-socket concept was the Medial Sphere knee. We report the five-year survivorship, clinical outcomes, patient reported outcome measures (PROMs) and radiographic analysis of this implant in a multi-centre, multi-surgeon prospective observational study.

Methods

Patients awaiting TKR who had no medical contraindication to surgery, were able to provide informed consent and were available for follow-up were recruited from four centres. Primary outcome was implant survival at six months, one, two, three and five years. Secondary outcomes were patient reported outcome measures: Oxford Knee Score (OKS), Euroqol (EQ-5D), International Knee Society Score (IKSS), IKSS Functional score and Health State score, complications and radiographic outcomes. Radiographic analysis was undertaken using the trauma cad software and data analysis was undertaken using SPSS.

Results

299 female and 181 male patients with a mean age 66.9 years and mean body mass index 30.0 were recruited. Five year Kaplan-Meier survivorship analysis of cumulative failure showed an implant survival of 99.46% (95% confidence interval 100 - 96.74), when deaths and withdrawals were treated as censored data. Eight patients withdrew (1.67%), six died (1.25%) and two knees were revised (0.41%).

The mean EQ5D, Health State Scores, OKS, IKSS & IKSS Function scores at five years improved significantly from pre-operative scores (Health State Score: 15.84 (65.54 pre-op to 81.38); OKS: 19.55 (19.74 pre-op to 39.31); IKSS: 39.87 (44.55 pre-op to 84.42); IKSS Function Score: 25.84 (49.16 pre-op to 75.00). The mean improvement of EQ5D at five years was: 0.43 (0.48 pre-op to 0.91).

Discussion

Survival of the GMK Sphere to five years in this study was over 99%. Risk of revision compares favourably with UK National Joint Registry (NJR) data. The improvements that are seen in patient reported outcome measures reflect an enhancement in patient function and quality of life.

Conclusion

At five years follow-up, the implant demonstrates satisfactory survival and outcomes. Patient matching and evaluation of more cases, at more time points will allow outcome comparison with other implant options.

#5862

Simultaneous Bilateral Total Knee Replacement Is Safe as Single Total Knee Replacement and It Is the Best Alternative for Gross Deformity

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INTRODUCTION:

Gross deformity such as severe flexion contraction or severe varus deformity in both knees is better corrected simultaneously to prevent recurrence of flexion contracture and also to have equal leg length which facilitate proper physiotherapy post operatively. However, there is great reluctance in many institute to perform Simultaneous Bilateral Total Knee Replacement (SBTKR) fearing higher complication rate. The purpose of this paper is to show that SBTKR is economical, safe and sometimes is necessary in gross deformity such as bilateral flexion contracture. In this paper we will review the most recent literature about SBTKR which support our argument. Also we will review our cases of over 7500 of SBTKR done at our institution. In this study we will focus on the process that we went through at our institution to upgrade our medical care to enable to do this SBTKR safely. We will share also our post-operative protocol and some hint on the administrative level in order to perform SBTKR.

METHODS:

In the last 20 years we performed over 7500 SBTKR, 15,000 implants. We have established at our institution a pre-operative team where this team included internist, physiotherapist, anesthesiologist and other medical sub specialty as recommended by the internist. The patient was pre-oped carefully and the extent of medical examination was determined by the internist and the anesthesiologist. Each patient care was determined preoperatively and also we have utilized special complexity scale that we have developed at our institution to reflect the complexity of the primary total knee replacement 1-5. The ASA and complexity scale is now routinely printed on our OR schedule. If the patient was cleared, SBTKR were carried on. The surgery is done first for the right side and after cementing the assistant will start the left side while the senior surgeon will clean the knee and then assist in the second knee. We have tried different modalities and the safest , less confusing was to first finish the first knee and after cementing the other limb was started by the assistant. The surgeon had only two assistants and one scrub nurse. Increasing the no. of assistant will make things more confusing. So we strongly recommend having only one senior surgeon. Post-operative care was almost identical to that of a single total knee replacement. We documented the complication rate, blood transfusion and unexpected ICU admission etc. in the SBTKR and we compared it to over 1000 cases of single knee replacement done at our institution by the same surgeon. The knee score was also was documented on both sides.

RESULTS:

Blood transfusion as much higher in SBTKR and in spite of using many methods to decrease blood loss we continued to have transfusion rate of 52%. We have established a Task Force that usually meets every two weeks in order to improve the medical conditions . Infection rate was the same in the single and SBTKR. Of interest of the fact that the no. of unexpected ICU admission dropped significantly in the second year- which could be related more to the cooperation and collaboration between the medical team.

DISCUSSION AND CONCLUSION:

SBTKR is safe as single knee replacement. It is needed in gross deformity and in non-ambulating patient. Getting the institution ready for such a procedure has to be organized through special Task Force and requires extensive collaboration among different part of the hospital dept. We strongly recommend doing SBTKR especially in patients who has a gross deformity and in non-ambulating patient.

#5551

Robotic-Arm Assisted Total Knee Arthroplasty Improves Early Functional Recovery and Time to Hospital Discharge Compared to Conventional Jig-Based Total Knee Arthroplasty: A Prospective Cohort Study

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Objective:

The objective of this study was to compare early postoperative functional outcomes and time to hospital discharge between conventional jig-based total knee arthroplasty and robotic-arm assisted total knee arthroplasty.

Methods:

This prospective cohort study included 40 consecutive patients undergoing conventional jig-based TKA followed by 40 consecutive patients receiving robotic-arm assisted TKA. All surgical procedures were performed by a single-surgeon using the medial parapatellar approach with identical implant designs and standardised postoperative inpatient rehabilitation. Inpatient functional outcomes and time to hospital discharge were collected in all study patients.

Results:

There were no systemic differences in baseline characteristics between the conventional jig-based TKA and robotic-arm assisted TKA treatment groups with respect to age (p=0-32), gender (p=0.50), body mass index (p=0.17), ASA score (p=0.88), and preoperative haemoglobin level (p=0.82). Robotic-arm assisted total knee arthroplasty was associated with reduced postoperative pain (P<0.001), decreased analgesia requirements (p<0.001), reduced intraoperative blood loss (p<0.001), shorter time to straight leg raise (p<0.001), decreased number of physiotherapy sessions (p<0.001), and improved maximum knee flexion at discharge (p<0.001) compared to conventional jig-based TKA (figures 1-2). Median time to hospital discharge in robotic-arm assisted TKA was 77 hours (IQR, 74-81) compared to 105 hours (IQR, 98-126 hours) in conventional jig-based TKA (p<0.001) (figure 3).

Conclusion:

Robotic-arm assisted TKA is associated with decreased pain, improved early functional recovery, and reduced time to hospital discharge compared to conventional jig-based TKA.

Clinical relevance:

Robotic-arm assisted surgery improves postoperative rehabilitation and time to hospital discharge in patients undergoing TKA.

Figures

Figure 1: Boxplot showing pain score as measured using the numerical rating scale in conventional jig-based TKA versus robotic-arm assisted TKA

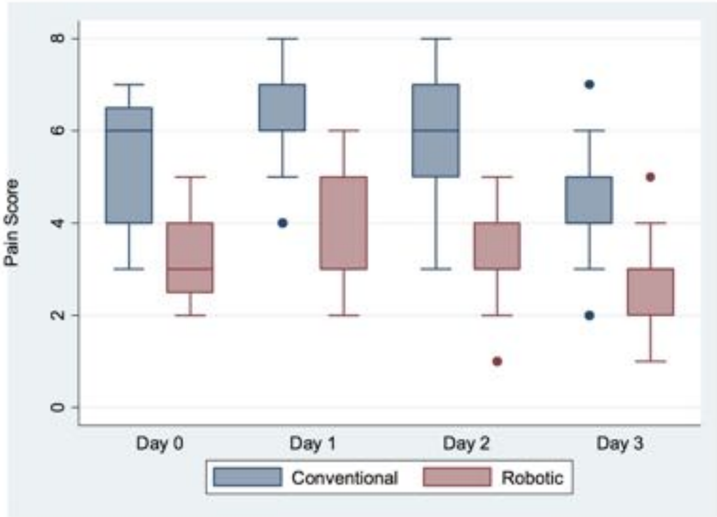

Figure 1

Figure 2: Boxplot showing opiate analgesia requirements in conventional jig-based TKA versus robotic-arm assisted TKA

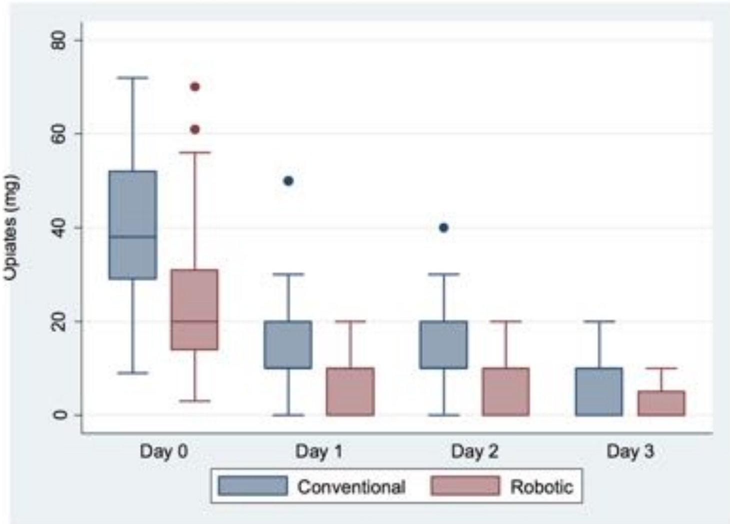

Figure 2

Figure 3: Boxplot showing time to hospital discharge (hours) in conventional jig-based TKA versus robotic-arm assisted TKA

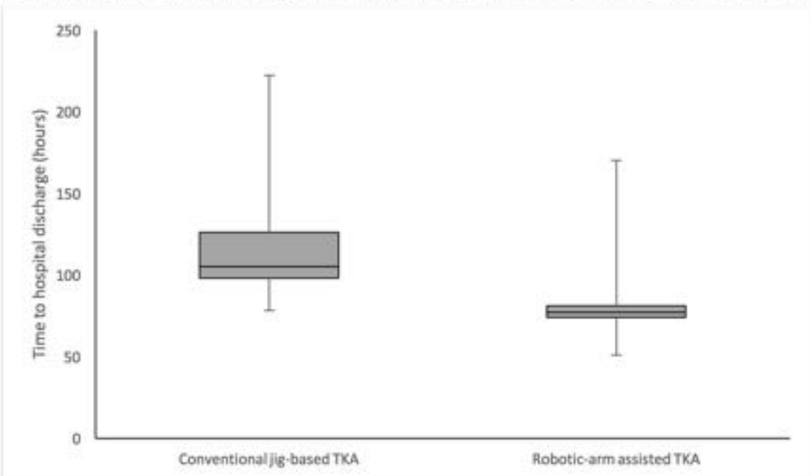

Figure 3

Central or Medial Pivot for Mobile-Bearing TKA: A Long Term Survivorship Analysis

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INTRODUCTION

Total knee arthroplasty (TKA) is a highly successful procedure. The use of a mobile bearing has been suggested to improve the functional results, decrease polyethylene wear and improve long term survival. However, clinical relevance of this design change remains debated. Furthermore, there is a debate about the design of the mobile piece, with either a central or medial pivoting axis. Few long term results have been documented. The present study was designed to evaluate the long-term (more than 10 years) results of mobile bearings TKAs on a national scale, and to compare the long term survivorship of central or medial pivot systems.

The primary hypothesis of this study will be that the 10 year survival rate of medial pivoting mobile bearing TKAs will be different from that of central pivoting mobile bearing TKAs.

METHODS

All patients operated on between 2001 and 2004 in all participating centers for implantation of a TKA (whatever design used) were eligible for this study. Usual demographic and peri-operative items have been recorded. All patients were contacted after the 10 year follow-up for repeat clinical and radiological examination (KSS, Oxford knee questionnaire and knee plain X-rays). Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information about prosthesis survival. Central pivot and medial pivot TKAs were paired according to age, gender, body mass index and severity of the coronal deformation (with steps of 5°). Survival curve was plotted according to the actuarial technique, using the revision for mechanical reason as end-point. The influence of the mobile bearing design was assessed with a logrank test at a 0.05 level of significance.

RESULTS

1,604 TKAs were implanted during the study time-frame. 1,154 cases could be paired in central pivot (577 cases) and medial pivot (577 cases) groups. There was no difference in any baseline criteria between both groups. 208 patients deceased before the 10 year follow up (18%). Final follow-up was obtained for 670 cases (58%). 22 prosthetic revisions were performed for mechanical reasons during the follow-up time (2%). The global survival rate after 14 years was 97%. There was no significant difference between the 13 year survival rates of central pivot (98%) and medial pivot (97%) TKAs.

DISCUSSION

The primary hypothesis of this study was not confirmed: no difference was observed between central pivot THAs and medial pivot TKAs when considering the 13 year survival rate for mechanical revision. The biomechanics of a normal knee is different between the medial femorotibial joint (more stable), and the lateral one (more mobile). It seems logical to adapt the design of a TKA to that feature. The medialization of the pivoting center of a mobile bearing TKA is supposed facilitating or even inducing a more physiologic kinematics. However, the results of the present study do not support this assumption. We suggest that the restoration of the ligament balance may be more critical than the design of the implants for restoration of a physiological kinematics.

#5597

Ten to Fifteen Year Survival of Navigation-Assisted Total Knee Arthroplasty.

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INTRODUCTION

Total knee arthroplasty (TKA) is a highly successful procedure. Survival rates of more than 90% after 10 years are generally reported. However, complications and revisions may still occur for many reasons, and some of them may be related to the operative technique. Computer assistance has been suggested to improve the accuracy of implantation of a TKA. Few long term results have been documented. The present study was designed to evaluate the long-term (more than 10 years) results of a TKA which was routinely implanted with help of a non-image based navigation system.

The hypothesis of this study was that the 10 to 15 year survival rate of this TKA will be improved in comparison to historical papers when analyzing survival rates.

MATERIAL AND METHODS

All patients operated on between 2001 and 2004 for implantation of a navigated TKA in the two participating centers were eligible for this study. Usual demographic and peri-operative items have been recorded. All patients were prospectively followed with clinical and radiological examination. All patients were contacted after the 10 year follow-up for repeat clinical and radiological examination (KSS, Oxford knee questionnaire and knee plain X-rays). Patients who did not return were interviewed by phone call. For patients lost of follow-up, family or general practitioner was contacted to obtain relevant information about prosthesis survival. Survival curve was plotted according to Kaplan-Meier.

RESULTS

578 TKAs were implanted during the study time-frame. 537 cases had an optimal lower limb axis (HKA angle between 177° and 183°) after TKA (93%). 116 patients deceased prior to the 10 year follow-up (20%). Final follow-up (including death or revision) was obtained for 439 cases (76%). Clinical status after 10 years was obtained for 341 cases (59%) (KSS, 254 cases – Oxford questionnaire, 299 cases – radiologic evaluation, 197 cases). 10 prosthetic revisions were performed for mechanical reasons during the follow-up time (2%). The global 10 year survival rate was 95.5%, and it decreased to 91.5% at 15 years. The 10 year survival rate for mechanical revision only was 98.0%, and decreased to 96.2% at 15 years (figure 1). The mean KSS at the last follow-up was 188 points, and the mean Oxford score was 55 points. No component was considered loose at the final radiographic evaluation. No polyethylene wear was detected at the final radiographic evaluation. No difference was observed between the two participating centers for any baseline or follow-up data.

DISCUSSION

The present study represents the longer follow-up of navigated TKAs published in the literature. This study confirms the satisfactory results of navigated implanted TKA after more than 10 years. Navigation probably contributed to the quality of the results. A more consistent anatomical reconstruction and ligamentous balance of the knee should lead to more consistent survival of the TKA. Other authors did observe similar results. However, superiority of navigated TKA in comparison to conventional implanted TKA is difficult to prove because of the subtle differences expected in mostly underpowered studies. Longer term follow-up may be required.

#5921

Implant Fixation and Early Clinical Outcomes of a 3D-Printed Acetabular Cup

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INTRODUCTION

Additive manufacturing (3D printing) is used to create porous surfaces that promote bone ingrowth in an effort to improve initial stability and optimize long-term biological fixation. The acetabular cup that was studied is manufactured with titanium alloy powder via electron beam melting. Electron beam melting integrates the porous and solid substrate rather than sintering a porous coating to a solid surface. The 3D-printed acetabular cup's high surface coefficient of friction (up to 1.2), combined with its geometry, creates a predictable press-fit in the acetabulum, improving initial mechanical stability and ultimately leading to reproducible biologic fixation. The objective of this study was to evaluate the early clinical outcomes and implant fixation of this 3D-printed acetabular cup in total hip arthroplasty (THA).

METHODS

Four hundred twenty-eight subjects from 8 US and international research sites underwent primary THA with the 3D-printed acetabular cup (Figure 1). All sites received IRB approval prior to conducting the study, and all participants signed the informed consent. Screw usage and number used during surgery were used as a surrogate measurement for initial implant fixation. Clinical performance outcomes included pre- and post-operative Harris Hip Scores (HHS) and Oxford Hip Scores (OHS), patient satisfaction, and revision assessment. 215 patients had a minimum 1-year post-operative follow-up visit. Student t-tests were used to identify significant mean differences ($p<0.05$).

RESULTS

Acetabular screws were used in 206 of 428 cases (48.1%); 85.9% used 1 screw, 12.6% used 2 screws, and 1.5% used 3 screws (Figure 2). The means and standard deviations for HHS and OHS are shown in Figure 3. For patients with a 1-year post-operative visit, the HHS improved by 49.8 points to 91.9 from 42.1, and the OHS improved by 27.7 points to 44.4 from 16.7. Patient satisfaction scores at the 1-year post-operative visit were 9.7 ± 0.7 (n=94). There was no significant difference between genders with regard to BMI, the 1-year post-operative HHS, OHS, or patient satisfaction scores. However, the males were significantly younger (59.8 vs. 62.9 years) and had significantly higher pre-operative HHS (45.7 vs. 37.9) and OHS scores (17.8 vs. 15.3). There were 9 revisions reported.

DISCUSSION

For initial implant fixation, compared to a similar, non-3D-printed acetabular cup in the same product line, the 3D-printed cup used significantly fewer screws per case (n=1 for 85.9% cases vs. n=2 for 85.7% of cases; Figure 2) in a fewer percentage of cases (48.1% vs. 70.4%), suggesting greater initial stability and "scratch fit". The 3D-printed acetabular cup also displayed positive early clinical results as evidenced by the pronounced improvement in clinical outcome scores from the pre-operative visit to the 1-year post-operative visit. These 1-year improvements are better than moderate clinically important improvements reported in the literature (40.1 points for HHS).[1] Patient satisfaction scores were also excellent (9.7/10). There were nine revisions; however, four of these were due to patient falls and one was due to infection.

SIGNIFICANCE

The 3D-printed acetabular cup evaluated in this study demonstrated improved implant fixation and positive early clinical outcomes for THA.

REFERENCES

[1]Singh et al. BMC Musculoskelet Disord,17:256,2016.

Figures

Figure 1. Subject Demographics – Values indicate Mean (Standard Deviation) or Counts (Percentage)

	Total Population n=428	Minimum 1-Year Follow-Up n=215
Age (years)	61.3 (11.0)	62.2 (10.3)
Gender	Female: 196 (46%)	Female: 97 (45%)
	Male: 232 (54%)	Male: 118 (55%)
Height (cm)	170.6 (9.9)	171.1 (9.7)
Weight (kg)	85.0 (18.9)	86.5 (18.9)
BMI	29.1 (5.5)	29.3 (5.4)
Diagnosis		
Primary Osteoarthritis	275 (64%)	163 (76%)
Secondary Osteoarthritis	27 (6%)	5 (2%)
Acute Fracture	1 (<1%)	0
Avascular Necrosis	54 (13%)	13 (6%)
Degenerative Joint Disease	114 (27%)	70 (33%)
Inflammatory Arthritis	6 (1%)	2 (1%)
Other	19 (4%)	12 (6%)

Multiple diagnoses may have been submitted for a single subject.
Date of surgery prior to January 1, 2018.

Figure 1

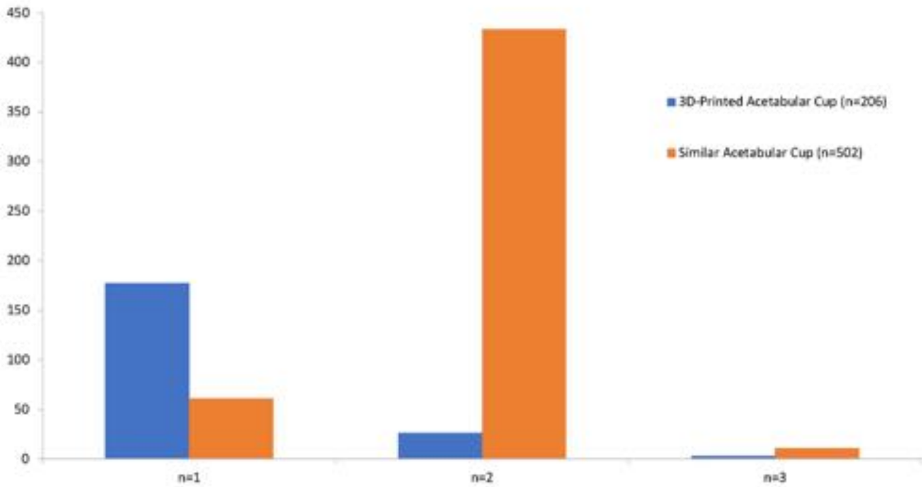

Figure 2. Screw Usage When Used per THA Case by Acetabular Cup (n=1, 2, or 3).

Figure 2

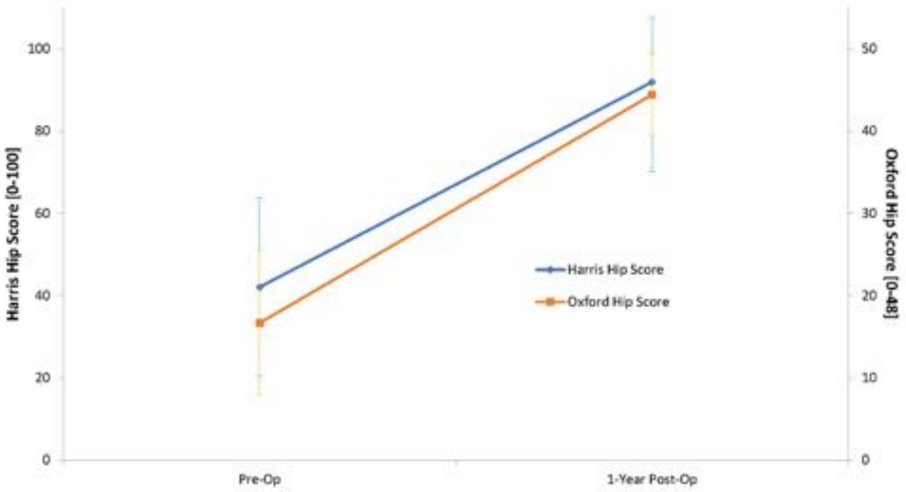

Figure 3. Clinical Outcomes Scores. Data represent means +/- standard deviation.

Figure 3

#6003

Managing the Large Acetabular Defect in Revision Hip Surgery: The Custom 3D Printed Titanium Solution.

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Introduction

Advances in additive manufacturing and three dimensional (3D) computed tomography have led to a new class of implants, custom printed titanium acetabular implants, which enable surgeons to manage massive acetabular defects in revision hip surgery. There is no reference standard for the reconstruction of patients with significant acetabular bone loss beyond Paprosky 3B, and there are no mid to long-term outcome studies of using custom 3D printed implants.

Aim: *We aimed to investigate the use of these custom 3D printed trabecular titanium implants for the management of massive acetabular defects,* ***Fig.1****.*

Materials and Methods

This study is a prospective consecutive case series of 20 patients from a single surgeon. The median age at surgery was 67 years (51–88); on average, these patients had 3 previous revision hip operations. All patients underwent a pre-op thin slice metal artefact reduction sequence (MARS) CT scan of their pelvis. The imaging data was used to produce a 3D reconstruction of the patient's bony pelvis for estimation of volume of bone loss, position of centre of rotation (CoR) of the failed hip and implant designing.

Post operatively, all patients had a CT scan which was reconstructed using state-of-the-art software solution to compute relevant biomechanical measurements including horizontal and vertical femoral offset, component position compared to planned: cup inclination and version angles in relation to the anterior pelvic plane, CoR measurements and screw engagement was also assessed,**Fig.2**.

Results

The median follow-up was 16 months (2-23), the median bone defect volume was 90 cm^3(40-234). One of the cases was revised at 2 months from the index operation. All other implanted devices showed satisfactory results with no evidence of infection or loosening.

The planned Vs achieved CoR had a median difference of 8 mm (3-26);**Fig 3**. Radiologically, the components were stable, and no screw breakages were identified.

Discussion

There is no consensus regarding the best option for reconstructing acetabular defects classified as Paprosky 3B or greater. We have evaluated a series of pre and post-operative methods for reconstruction of unclassifiable acetabular bony defects. Early clinical and radiological results are promising considering the severity of the acetabular bony defects.

Conclusion

Custom 3D printed titanium implants constitute a viable option to accurately reconstruct previously unreconstructable defects allowing a detailed surgical planning that helps reducing implant inventory.

Figures

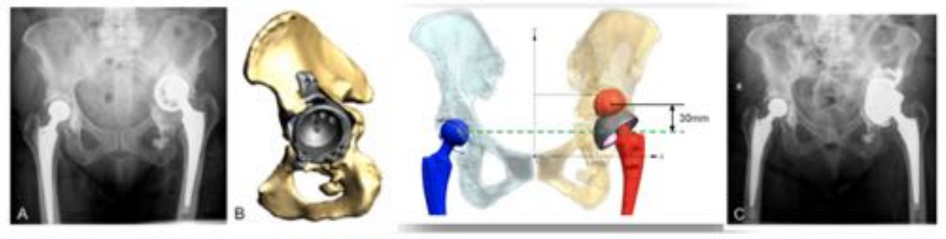

Fig. 1: A) Pre-operative AP radiograph demonstrating superior and medial migration of the acetabular component, B) 3D computer model of the pre-operative hemipelvis with computed CoR C) the post-operative radiograph showing the restored CoR.

Figure 1

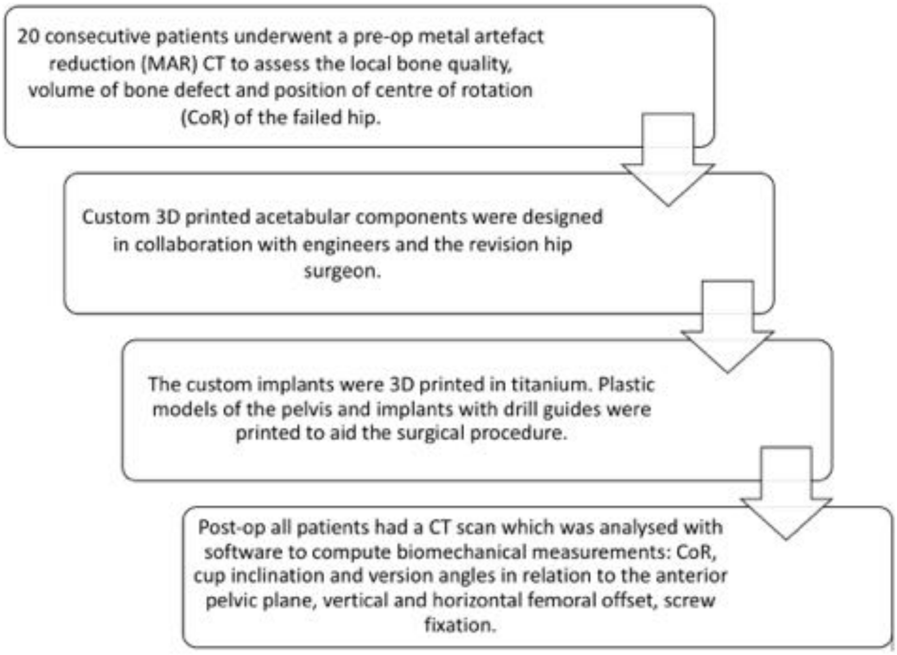

Fig.2: Flow chart of the methodology.

Figure 2

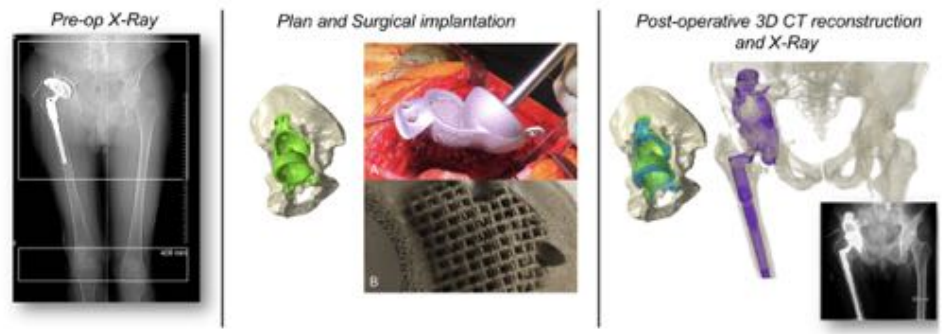

Fig. 3: Case example with Planned Vs Achieved CoR (y) =3mm: (left image) Pre-operative X-Ray; (middle image) Plan and surgical implantation of the custom trabecular titanium acetabular cup showing the trabecular material used on the back of the implant to increase osseointegration; and (right image) Post-operative 3D CT reconstruction of the implant and X-ray.

Figure 3

#5971

Satisfactory Clinical Results at 2-Years Follow-Up of a New 3d-Printed Custom-Made Acetabular Implant for Paprosky 3 Defects

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Introduction

Acetabular revision is a challenging operation in cases with major bone loss and poor bone quality. Research suggests custom-made implants might be the best alternative to handle large defects in previous failed reconstructions, but few reports of sufficient quality are available yet.The purpose is to evaluate the clinical performance of a new custom-madetitanium implantdesigned from a detailed CT-based analysis of the defect with special reference to bone quality and the anatomy of the bone deficient acetabulum.

Methods

A cohort of 32 consecutive patients with Paprosky type 3B defects were included. All patients (20 women, median age 68 years [range 48-89], median BMI 28 [range 20-44]) had a minimum follow up of 2 years. Clinical results and safety parameters were evaluated preoperatively and postoperatively at 4 months, at 1 year and at 2-years follow up (2yrFU). Our primary outcome was the modified Oxford Hip Score (OHS) (mean [SD]) preoperatively versus at 2yrFU. Secondary outcome measurements included the Euroqol-5-dimensions 3 level (EQ5D-3L) utility, EQ5D-3L NRS (0-100), VAS for pain in rest and during activities and satisfaction with surgical result (VAS). Our primary outcome (OHS) was parametrically tested to evaluate clinical performance over time ($p<0.05$). Our secondary outcome data were descriptively summarized (median [ranges]). Patients also answered questions on general health and satisfaction during follow up. Complications and X-rays were assessed at follow up.

Results

25 patients had complete clinical follow up for the OHS. The non-responders (n=7) did not differ on baseline characteristics There was a significant improvement over time ($F[3,22]=158.3$, $p<0.001$) for the OHS (pre-op 51 [12]; 2yrFU 29 [10]). Our secondary outcome measures seemed to have improved as well over time: EQ5D utility (pre-op 0.216 [-0.128-0.920]; 2yrFU 0.747 [0.216-1]); EQ NRS (pre-op 50 [7-100]; 2yrFU 70 [40-90]); VASrest (pre-op 53 [0-100]; 2yrFU 2 [0-65]) and VASactivity (pre-op 89 [1-100]; 2yrFU 11 [0-65]).

At 2yrFU 27/29 patients were satisfied with the overall result, 24/30 reported improved daily functioning and 29/30 reported less pain since surgery.

In total 9 complications occurred in 8 patients. No revisions occurred and 3 re-operations were performed. All reoperations were debridement for delayed wound healing. One of these had a culture proven infection, which was treated with antibiotics. 3/31 patients showed signs of screw loosening with no migration of the implant at 2yrFU. These 3 patients had loose ischium screws, 1 of these had loose pubic screws as well.

Conclusion

The preliminary study results show satisfactory clinical outcomes, especially when compared to the limited literature available on custom-made acetabular implants. To our knowledge we are the first to present two-year follow-up results of patients who received this new personalized and custom-made hip implant for large acetabular defects.

#5900

Retrieval Analysis of 3D Printed Titanium Orthopaedic Implants

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Introduction

The use of Additive Manufacturing (AM) to 3D print titanium implants is becoming widespread in orthopaedics, particularly in producing cementless porous acetabular components that are either *custom-made* or *off-the-shelf*; the primary design rationale for this is enhanced bony fixation by matching the porosity of bone. Analysis of these retrieved components can help us understand their performance; in this study we introduce a non-destructive method of the retrieval analysis of 3D printed implants.

Material and methods

We examined 11 retrieved 3D printed acetabular cups from one manufacturer (Lima Corporate, Udine, Italy), divided into two groups: "*custom-made*" (Promade, n = 4) and "*off-the-shelf*" (Delta TT and Delta ONE TT designs, n = 7) (Figure 1). A macroscopic visual analysis was initially performed to measure the area of tissue ongrowth. High resolution imaging of each component was captured using a micro-CT scanner (XTH 225, Nikon Metrology NV) and 3D reconstructed models were used to assess clinically relevant morphometric features of the porous structure: porosity, porous structure thickness, pore size and strut thickness (Figure 2). Optical microscopy was also used as a comparison with microCT results. Surface morphology and elemental composition of the implants were investigated with a Scanning Electron Microscope (SEM) coupled with an Energy Dispersive X-ray Spectroscope (EDS). Statistical analysis was performed to evaluate possible differences between the two groups.

Results

We found a spread of tissue coverage, median of 81% (23 - 95), with a trend with time *in situ*. *Custom* implants showed a high spread of porosity, with a median of 74.11% (67.94 - 81.01), due to the presence of differently designed porous areas. *Off-the-shelf* cups had a median porosity of 72.49% (66.67 - 73.07), but there was no significant difference between the two groups ($p = 0.164$). There was a significant difference in the thickness of the porous structure of the *custom* and *off-the-shelf* groups, which were 3.918 mm (3.688 – 4.102) and 1.289 mm (1.235 – 1.364), respectively ($p = 0.006$). SEM output showed specific morphological features of 3D printed object (Figure 3); EDS analysis suggested that no chemical modifications occurred *in vivo*, with elemental ratios (Ti/Al = 14; Ti/V = 21; Al/V = 1.51) comparable to previously published results.

Conclusion

This is one of the first retrieval studies of 3D printed orthopaedic implants. We introduced a method for the investigation of these components and micro-CT scanning enabled the non-destructive assessment of the porous structure. This work represents the first step in understanding the performance of 3D printed implants.

Figures

Figure 1

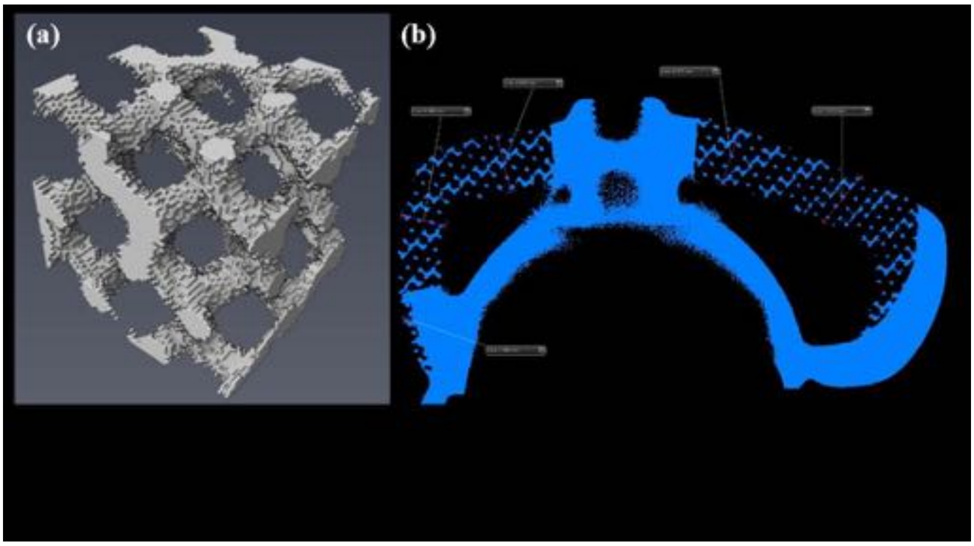

Figure 2

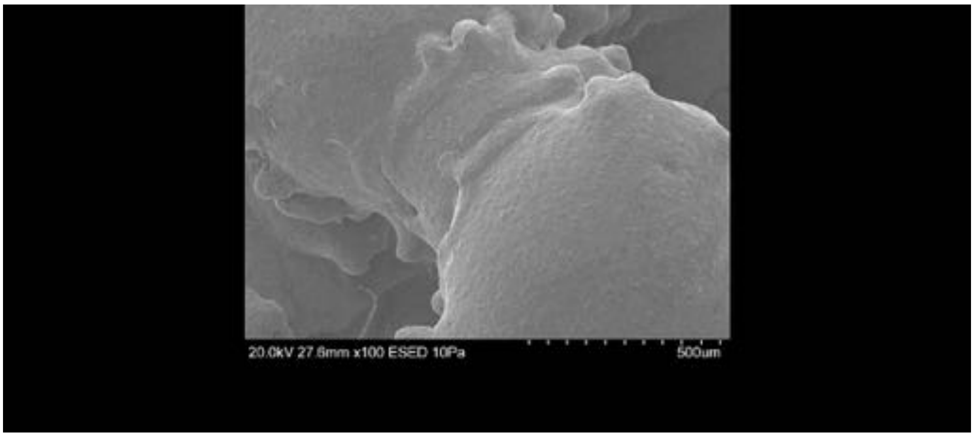

Figure 3

#5707

Optimisation of 3D Printed Porous Structures for Bone Ingrowth

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Introduction

High strength porous implants can now be manufactured through selective laser sintering (SLS). Extensive porous structures in the forms of cones and augments have been used for revision arthroplasty. A method to optimise the design of implants is by minimising the structural stiffness of the implants to enhance bone formation [1]. The use of electrochemical coating of hydroxyapatite (HA) is known to promote osseointegration [2] but the two approaches have not been thoroughly considered together to design implants and evaluate their performance. The bone ingrowth scaffolds with different pore sizes and coating were evaluated in an ovine condylar femoral defect model, and used to build a finite element model that uses two new algorithms for adventitious bone formation to provide a quantitative basis for evaluating scaffold design and material selection.

Methodology

Porous Ti6Al4V scaffolds were manufactured using SLS with pore sizes of 1500 and 700 microns and half of the scaffolds were electrochemically coated with hydroxyapatite. After 6 weeks in situ, the implants were retrieved for histological analysis. The surface integration and proportion of bone growth were measured in ImageJ. Finite element analysis (FEA) models were developed with the scaffold implanted in trabecular bone and soft tissue was assumed to fill the pores of the implants. A uniform pressure load corresponding to peak value in the gait of a sheep was applied. A novel algorithm for adventitious bone formation was implemented by allowing the soft tissue adjacent to bone and remodelled elements to adapt its density. Osteoconduction was modelled by preferentially allowing soft tissues in contact with the coated implant surfaces to form bone. The material properties of the implants were also varied to assess the influence on bone ingrowth and osseointegration. The stress and strain environment in the implant and tissues were assessed before and during remodelling, and when bone ingrowth had reached equilibrium. The volume of bone ingrowth and surface integration were also determined at equilibrium.

Results and discussion

The non-coated plugs osseointegrated only at the implant surface, whereas, electrochemically coated plugs exhibited significantly greater osseointegration on all internal surfaces ($p<0.001$). The FEA models validated well with the in vivo study (Fig1). The use of conductivity increased the volume of bone formation by 31% and 65%, from 34% and 23%, for the 1500 and 700 microns plug sizes respectively. Bone formation reduced stress concentrations at geometrical shape changes by at least 20%. This improves the implant’s long-term fatigue resistance, as excessively high strain in the tissue is reduced to safe levels as bone forms. The use of low modulus Titanium-Tantalum alloy (Ti-70%Ta) instead of Ti6Al4V reduced stress shielding and increased bone ingrowth to over 56%. A balance between bone formation, structural stiffness and fatigue resistance is required and needs to be considered carefully where extensive porous structures, made by additive manufacturing, are being used.

Acknowledgements

This work was funded by Orthopaedic Research UK (grant #515).

References

[1] Arabnejad S, et al. *Acta Biomater* 30:345-56, 2016

[2] Mumith A, et al. *Bone & Joint J* 99-B:276–82, 2017

Figures

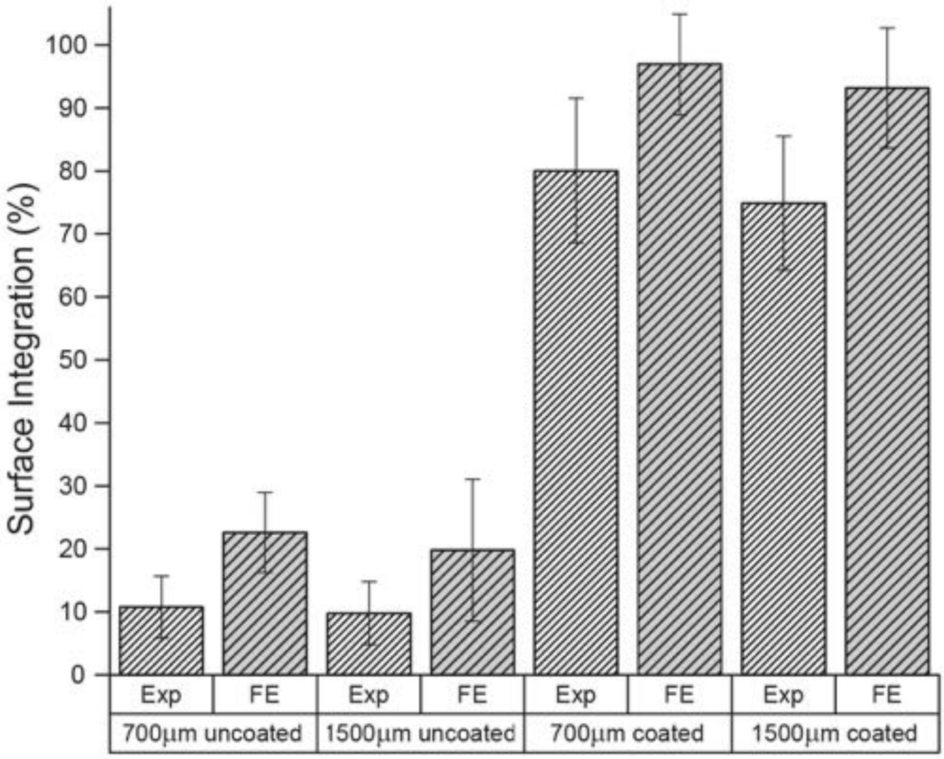

Figure 1

#5844

Material Properties of Laser 3D Printing Products and Conventional Role Titanium in Many Conditions

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Introduction

To manufacture custom implants 3D printing is regarded as one of very useful technique. When we use them, the material properties of the 3D printing products in many conditions are very important. Electron Beam Melting (EBM), is a most popular method used to manufacture orthopaedic products. According to several studies, EBM products tensile strength is 80-95% of the conventional material. Another method is Selective Laser Melting (SLM). But at present as long as we can research no orthopaedic product is manufactured by this method. In the present study, we have manufactured test peaces using SLM, in different conditions then we have compared the material propaties to convetional role titanium material. Ministry of Economy, Trade and Industry supported this study.

Materials and Methods

For SLM manufacturing, EOS M280 was used. For the control, conventional role titanium material was used. Both all test peaces were finished by CNC to meet Japanese Industrial Standards (JIS) test peace (JIS Z 2201, #14A). Test peaces manufacturing was done, in different direction (horizontal and vertical) , in the different area of the table (center and edge), different repetition of the powder (all brand new and after repetition of the usage). Using Autograph AG-50kNG M1 (Shimadzu, Japan) traction tests were performed.

Results

1) Conventional vs. SLM (each 4 peaces)

Tensile strength of the Conventional was 997.4±4.42 MPa, that of SLM was 1260.9±22.0 MPa P=0.000098. SLM was 26.5% stronger.

2) Table centre vs. table edge (each 6 peaces)

Tensile strength of centre was 1259.9±23.7 MPa, and that of table edge was 1266.7±15.6 MPa. P=0.663 N.S.

3) Layer direction (each 6 peaces)

with layers perpendicular to the traction: 1246.2±9.8 MPa, with layers parallel to the traction: 1280.4±18.8 MPa, P=0.013. Perpendicular peaces had 3% less. But it was still 26% more than that of conventional peace.

4) The powder remained will be reused in 3D printers. Difference of repetition.

i) The tensile strength of test peaces made of virgin powder: 1260.0±17.8 MPa

ii) That of secondary powder: 1280.0±26.9MPa

iii) Thirdly powder: 1249.0±10.4MPa

No significance was shown.

Ddifferent from EBM result which has 80-95% less than conventional, SLM results has shown about 25% stronger in any condition.

Discussion

EBM method is regarded to have bigger titanium tissue. Then it has less traction strength than the conventional method. As for repeated powder, EBM use preheating to all the material. So all secondary EBM powder should have been already heated. On the contrary, SLM powder was not.

Conclusion

SLM products were stronger than the products made by conventional method.

Figures

Figure 1

#6020

Challenging the Doctrine That Larger Contact Area Reduces Wear of Total Knee Replacements?

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Abstract

From the onset of Total Knee Replacement (TKR) design, it is known that large articular contact surface area is sought to reduce stress to reduce wear of the UHMWPE tibial bearings. Early generations of UHMWPE TKR bearings showed excessive wear due to delamination by stress fatigue, caused by oxidation from sterilization by gamma radiation in air, and from excessive shelf lives. Reducing stress with higher contact area was a wise solution then, but came at a price of increased TKR constraint. The latter could curtail range of motion and impart higher forces and torques to the bone or cement interface and risk implant loosening. In this study we questioned the widely held belief that higher contact area leads to lower wear in modern TKR designs and materials where the risk of delamination fatigue wear has been largely eradicated.

We pooled data from eight full-scale knee wear simulator tests performed in our lab on different TKR designs, materials and conditions. Each test had a sample size range of 2-4 per sub-group and compared the wear rate of large versus small(er) size TKRs which were otherwise identical in every way. TKR size was used as surrogate variable to represent contact areas by scaling, but it may have also increased sliding distances as a confounding variable. We used the same force-control testing methodology of ISO 14243-1&2 simulating human walking, under the same dynamic multi-axial loads, The UHMWPE wear was measured gravimetrically in tests which ran for at least 5 million cycles (MC), except for two shorter (2 MC) tests with accelerated abrasive wear conditions. Statistical significant difference tests compared the wear between larger and smaller TKRs in each group. The anterior-posterior (AP) linear and internal-external (IE) rotational kinematics were measured from the force-controlled simulator and compared to assess the effect of TKR size on kinematics, and the effect of the accumulated sliding distances per cycle on wear as confounding variables. The wear scar (patch) areas on the tibial bearings were also measured at the end of each test. Six separate correlation analyses were performed to see if the higher accumulated sliding distances expected with larger TKR sizes could have been the main reason behind extra wear, and if those kinematics and wear scar/patch areas correlated with extra wear too.

None of UHMWPE bearings of the14 sub-groups (7 pairs of large vs. small sub-groups) showed any signs of delamination wear. Their wear rates varied among the TKR designs and UHMWPE materials, and, as expected, the extra abrasion tests showed significantly higher wear ($p<<0.050$) than their respective controls. In all the eight tests including the two extra-abrasive tests, the wear of the larger size TKR was statistically significantly higher ($p\leq0.05$) than its equivalent smaller version. The difference in wear (size effect) varied since the difference in sizes of the implants tested was not the same. The correlation analyses failed to attribute this wear increase solely or even primarily to increased sliding distances.

Our study associated increasing TKR size with increased wear, primarily due to contact area differences. Decreasing contact area is not a good general solution however, as excessively higher contact pressure/stress would result with contact areas too small,

turning the trend into higher wear. Therefore, an optimum contact area should be chosen to balance these effects, selected primarily for optimum constraint for better TKR function.

Similar findings to this study could be interpreted from some published pin-on-disk test results, other TKR tests, and of course from total hip replacements. Larger hips are known to wear more than smaller ones under the same loads despite their lower contact stresses, due to larger contact areas and sliding distances. Our data sheds doubt on the previous doctrine, offering a new beacon to guide future knee designers to be wary of excessively high TKR contact area. With everything else equal, larger TKRs wear more than smaller ones. With equally sized contemporary designs and similar kinematics, a TKR with more conforming articular surfaces may wear more than less-conforming designs. With modern materials and processing, increasing contact area to decrease contact stress may be counter-productive and may result in increased wear.

#5986

Early Results of a Modern, Uncemented Total Knee Arthroplasty System

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ABSTRACT:

The use of uncemented knees is growing; in addition to the desire for better survivorship, the procedure is appealing as it is faster, has no cement mess, and creates less anxiety in the OR. To assess the impact on the 90-day global risk period, we compared outcomes, length of stay, complications, ER-visits, readmissions and financial data in age-matched cemented versus uncemented knees. Uncemented had shorter length of stay (1.58 vs. 1.87, p<0.0001) and were more frequently discharged home (90.48% vs. 68.75%; p<0.0001). More uncemented knees had “no complications” (216 vs. 193, p=0.0028), had less returns to OR (0 vs. 19, p<0.0001) and manipulations (0 vs. 14, p=0.0028). They scored better on KOOS (63.69 vs. 47.10, n=85 and 43, p<0.0001), and PROMIS T-physical and T-mental (44.12 vs. 39.45, p<0.0001; 51.84 vs 47.82 p=0.0018). Importantly, uncemented procedures had $1,095 less surgical episode cost (p< 0.001) and a 90-day comparative cost savings of over $1,300 (p< 0.001). Modern uncemented implants are performing as well or better during a 90-day global risk period than cemented designs both clinically and economically. These data should alleviate fears of increased cost, early failure, complications or poor outcomes with the use of a modern uncemented implants.

Key Words: uncemented knees; cemented knees; total knee arthroplasty; early outcomes; performance

#5940

What Makes Revision TKR Difficult: A Study of Fellowship Trainees and Young Joint Surgeons?

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INTRODUCTION: The demands placed upon joint surgeons are perhaps greatest when treating the revision arthroplasty patient, who present with complications demanding skill in diagnosis and evaluation, interpersonal communication and the technical aspects of the revision procedure. However, little information exists identifying which specific tasks in revision arthroplasty are most difficult for surgeons to master, and whether the greatest challenges arise from clinical, cognitive or technical facets of patient treatment. The following study was undertaken to identify which tasks associated with revision total knee replacement (TKR) are perceived as most challenging to young surgeons and trainees to guide future efforts in surgical training and curriculum development.

METHODS: We developed an online survey instrument consisting of 69 items encompassing pre-operative, intraoperative, and post-operative tasks that preliminary studies identified as the essential components of revision total knee arthroplasty. These tasks encompassed 4 domains: clinical decision-making skills (n=9), interpersonal assessment and communication (n=7), surgical decision-making (n=35) and procedural surgical tasks (n=18). Respondents rated the difficulty of each item on a 5-level Likert scale, with an ordinal score ranging from 1 (“very easy”) to 5 (“very difficult”. The survey instrument was administered to a cohort of 109 US surgeons: 31 trainees enrolled in a joint fellowship program (Fellows) and 78 surgeons who had graduated from a joint fellowship program within the previous 10 years (Joint Surgeons). Using appropriate parametric and non-parametric tests, the responses were analyzed to examine the variation of reported difficulty of each of the 69 items, in addition to the nature of the task (cognitive, surgical, clinical and interpersonal), and differences between Fellows and Surgeons.

RESULTS: Both Fellows and Surgeons reported a wide variation in the difficulty of performing the tasks identified in each f the 4 domains. Fellows reported a higher average difficulty score than Surgeons (2.94 vs 2.74; p=0.032), corresponding to a greater frequency of tasks entailing some degree of difficulty (34.9% vs 24.4%, p<0.0001). Both groups experienced difficulty in performing tasks involving interpersonal interaction with patients (Fellows: 34.6% vs Surgeons: 34.3%, p=0.93). Fellows also found the technical aspects of revision surgery most challenging with 38.5% of items considered difficult compared to 28.7% for the Surgeon group (p<0.001). Highly significant differences between Fellows and Surgeons were also observed in facility with surgical decision making (p<0.001) and to a lesser extent, clinical decisions relating to patient care (% difficulty: p=0.0251). A compilation of the specific items cited as most difficult by the participants appears in Table 2.

CONCLUSIONS:

1. The young surgeons surveyed in this study reported difficulty in performing some

tasks within both the clinical, cognitive and technical domains of revision knee arthroplasty.

2. The high incidence of difficulty in tasks involving clinical decision-making and operative performance are characterized by a lack of accepted guidelines and the lack of a standard surgical practice.

3. In general, our findings highlight the need for improvements in surgeon training to improve decision-making and procedural skills as part of the comprehensive management of patients undergoing revision knee arthroplasty.

Figures

Task Domain	Average Difficulty Score (SD)			% Reporting Some Difficulty		
	Fellows	Surgeons	p-value	Fellows	Surgeons	p-value
Clinical/Interpersonal	3.17 (0.92)	2.89 (0.97)	0.0004	34.6	34.3	0.9329
Clinical/Cognitive	2.79 (1.06)	2.66 (1.13)	0.0922	35.1	27.8	0.0251
Surgical/Cognitive	2.92 (0.94)	2.52 (1.00)	< 0.001	33.1	19.4	< 0.001
Surgical/Technical	3.17 (0.96)	2.80 (1.05)	< 0.001	38.5	28.7	< 0.001

Table 1. Average difficulty scores reported by Fellows and Surgeons for tasks within each of the 4 domains. The percentage of respondents reporting some degree of difficulty is also presented.

Figure 1

Moderately Difficult Activities
1. Managing a preoperative flexion contracture.
2. Judging the original level of the joint line.
3. Assessing if the patient understands the likely outcomes from treatment.
4. Determining the origin of the patient's symptoms.
5. Mobilizing the patella and extensor mechanism for exposure.
6. Making the diagnosis of infection when a cultured aspirate fails to grow an organism.
7. Assessing if the patient understands the risks of the revision operation.
8. Restoring an acceptable joint line using the landmarks present at revision.
9. Deciding when to use a perimeter cone and then implanting it in the femur or tibia.
10. Determining if the patient will actively participate in his/her recovery.
11. Selecting the appropriate internal/external rotation of the femoral component.
12. Determining the amount of cortical contact needed for cementless stem fixation.
Very Difficult Activities
1. Addressing a deficiency of the extensor mechanism.
2. Deciding how to treat the patient with knee pain and normal x-rays and lab values.
3. Managing diaphyseal defects.
4. Performing a safe and reliable tubercle osteotomy.
5. Deciding how to proceed when your clinical impression suggests infection but the lab results are unrevealing.
6. Deciding correct component alignment in a bowed tibia or femur.

Table 2. Specific tasks in revision TKR that were rated as moderately difficult or very difficult.

Figure 2

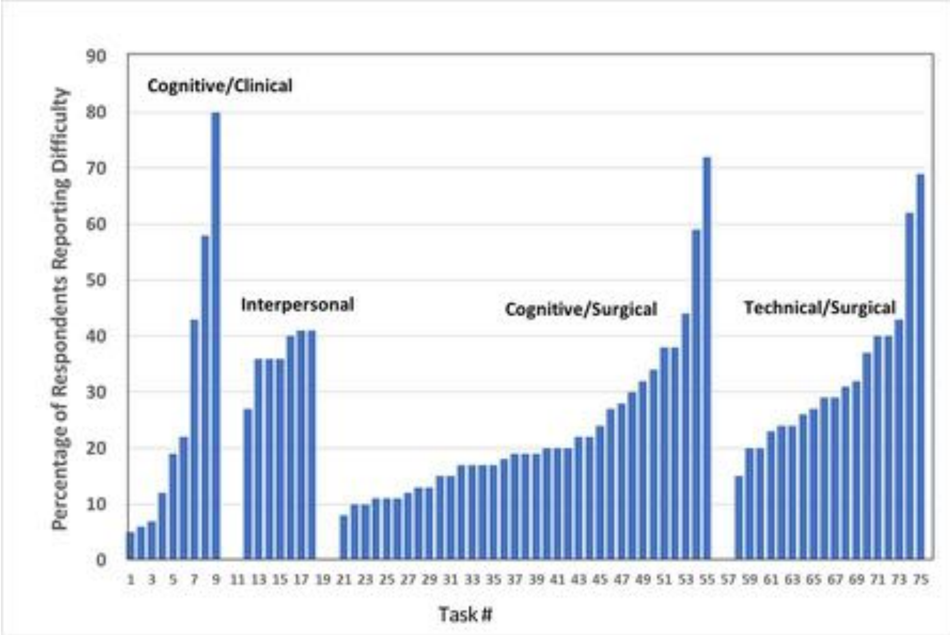

Figure 1. Percentage of Responses to Each Item on the Survey indicating Difficulty in Performing a Task, arranged by Domain.

Figure 3

#5984

Statistical Shape Modelling of the Femoral and Tibial Metaphysis for Applications to Revision TKA Design

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Introduction

Removal of primary components during revision TKA procedure can damage underlying bone, resulting in defects that may need filled for stability of the revision reconstruction. Special revision components including cones and/or augments are often used to compensate for the missing bones [1, 2]. Little work has been done to characterize metaphyseal geometry in the vicinity of the knee joint, however, in order to motivate proper size and shape of cones and augments. The objective of this study was to use statistical shape modelling to evaluate variation in endosteal anatomy for revision TKA.

Methods

Digital models of the femur and tibia were generated through segmentation of computed tomography scans, for the femur and the tibia (n~500). Custom software was used to perform virtual surgery and statistical shape analysis of the metaphyseal geometry.

Femoral bones were grouped according to size, in order to assess shape differences on a size-by-size basis; analysis was also conducted across the entire cohort. A representative and appropriately sized revision femoral component was placed on each bone, assuming anterior referencing. The component was externally rotated 3 degrees from the posterior condyle axis. The outer and inner boundaries of the cortical bone were determined at the resection level and at 5 mm increments proximally, up to 40mm. Similar analyses were performed on the tibia, using a typical revision resection (0 degrees medial and posterior slope), with outer and inner boundaries of the cortical bone were determined in 5 mm increments up to 40mm distal to the resection.

Metaphyseal geometry contours were exported relative to the central fixation feature of the implant, and average geometries were calculated based on size, and across the entire cohort. Principle Component Analysis (PCA) was used to quantify the variability in shape, specifically to evaluate the +/- 1 and 2 standard deviation geometries at each cross section level.

Results

Figure 2a shows the average inner metaphyseal geometry of the femur, taken 30 mm proximal to the distal resection plane, for different sizes of the femur, illustrating how the average geometry changes with bone size. Figure 2b shows the overall average tibia metaphyseal geometry from 0-40mm into the metaphysis. The +/- 1 and 2 standard deviation geometries at the 20mm level for both the tibia and the femur are shown in Figure 3; similar qualitative trends were observed at other resection levels.

Discussion

The generated contours can be used as a design input to optimize the shape of cones and augments, in order to fit potential defects in the femur and tibia encountered during revision TKA while respecting the anatomical constraints of the bone. Statistical shape analysis shows that these constraints are not strictly uniform scaling, based on bone size or on location in the metaphysis, but rather reflect variations in shape that may be used to optimize fill and stability of the prostheses.

Figures

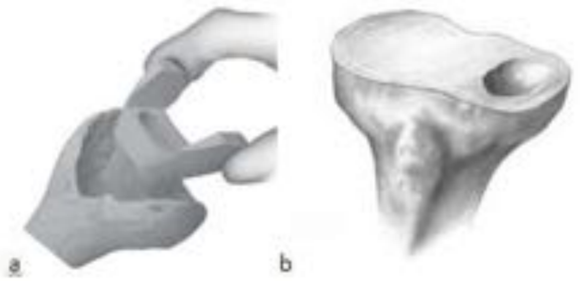

Figure 1. a) Femur with defect and cone trial b) Tibia constrained defect

Figure 1

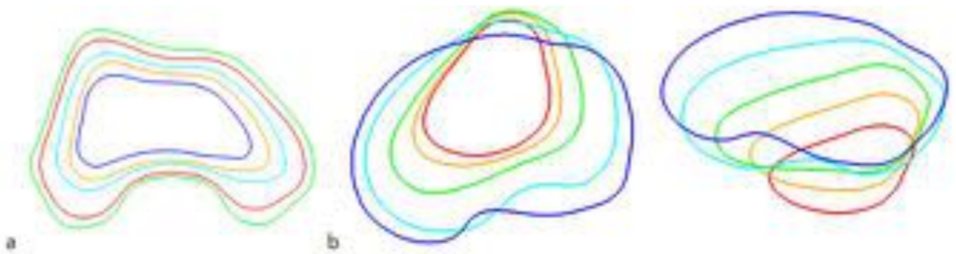

Figure 2. a) Size grouped average femur inner metaphyseal geometry at 30 mm from distal tangent plane. b) Overall average tibia metaphyseal geometry at 0 (blue), 10, 20, 30 and 40 (red) mm from tibia resection plane

Figure 2

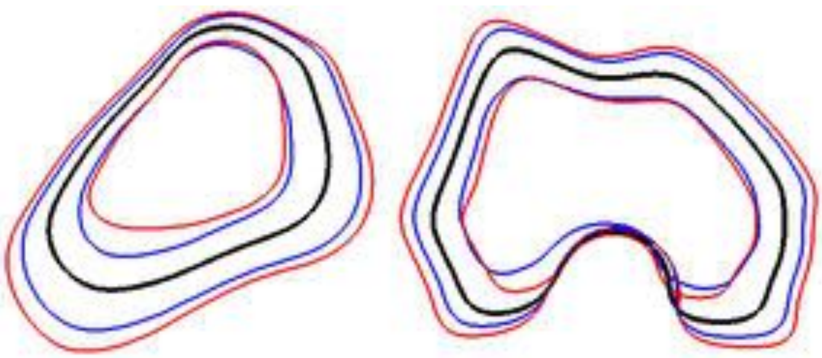

Figure 3. Primary mode of shape variation at 20 mm offset in the (a) tibia and (b) femur. Black contours show average metaphyseal geometry, red contours show +/- 1 standard deviations, blue contours show +/- 2 standard deviations.

Figure 3

Assessing Effects of Implant Geometry on the Loaded Stability Envelope of the Contemporary Revision Knee System

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Motivation

Revision Total Knee Arthroplasty (rTKA) is commonly used to revise a failed initial primary procedure or to address severe deformities in a complex primary procedure. In both situations, residual knee instability could pose challenges in achieving satisfactory soft tissue balance [1]. These concerns can be addressed by increasing tibiofemoral conformity in the Revision knee systems. However, highly conforming designs may restrict the tibiofemoral kinematic freedom at a joint. Therefore, the Revision knee system must provide sufficient joint stability without constraining the desired kinematic freedom. The objective of this study was to assess the effects of tibiofemoral conformity on the kinematic freedom during dynamic weight-bearing simulations in cadavers for three contemporary Revision knee systems.

Methods

Nine cadaveric knees (age: 69.5±18.5 years, BMI 25.3±4.3) were implanted with a DePuy Synthes ATTUNE® REVISION (N:4), Zimmer Biomet NexGen® LCCK (N:2), or a Zimmer Biomet Vanguard® 360 (N:3) Revision knee system by a trained orthopedic surgeon. Each knee was mounted and aligned in the Kansas Knee Simulator. A dynamically simulated weight-bearing activity flexed the knee from full extension to approximately 110° flexion, while the medial-lateral (ML) translation, internal-external (IE), and varus-valgus (VV) rotations at the ankle were unconstrained. Three profiles with increasing IE torques were applied to each knee (Fig. 1). The kinematics were described using a clinical coordinate system[1] and the change in motion from the fully applied torque to zero applied torque was calculated.

Results

The change in varus-vagus motion with an increased IE torque was minimal for all three systems (Fig. 2). However, an increased IE torque showed an increase in IE rotational motion for the ATTUNE® REVISION knee compared to the NexGen® LCCK and Vanguard® 360 Revision knee systems (Fig. 3).

Discussion

The ATTUNE® REVISION implants were designed to offer similar VV degree-of-freedom (Attune and NexGen: ±1.25â°, Vanguard: ±1.0â°), while allowing more IE rotational freedom (Attune: ±4.0â° and NexGen: ±2.0â°, Vanguard: ±0.5â°) [2]. The observed results showed the contribution of the intended constraints during simulated weight-bearing activities. The highly constrained designs rely less on the soft tissue contribution and consequently increase the stresses on the implant-bone interface [3]. Our results demonstrated that at peak flexion angle of a simulated weight-bearing activity, the specimen with ATTUNE® REVISION implants had increased freedom in IE rotation while the VV rotation remained constrained. The additional IE rotational freedom observed in ATTUNE® REVISION implants could promote soft tissue contribution, while achieving desire VV stability. In summary, ATTUNE® REVISION implants provided VV stability similar to the other two designs while offering IE rotational freedom during simulated weight-bearing activity.

References

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Figures

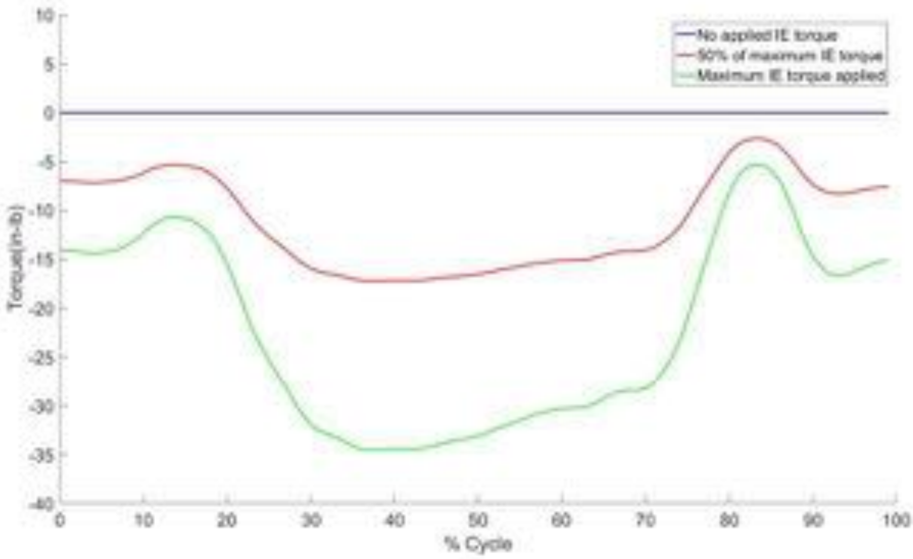

Figure 1: Applied torque about the tibial long axis during dynamic simulated weight-bearing activity. Each knee had a cycle with 0 IE torque as well as a cycle with applied torque shown.

Figure 1

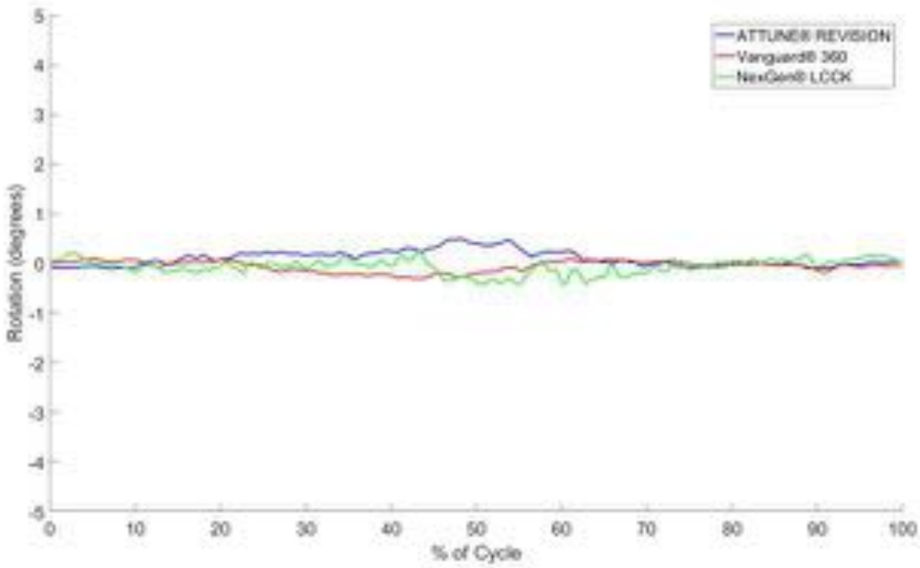

Figure 2: Change in tibiofemoral, VV kinematics during simulated activity. The kinematics from the activity without torque was subtracted from the cycle with torque. The range of change in rotation, averaged across the cycle for knees with an ATTUNE® REVISION implant was 0.66°, for Vanguard® 360 was 0.32°, and for NexGen® LCCK was 0.24°.

Figure 2

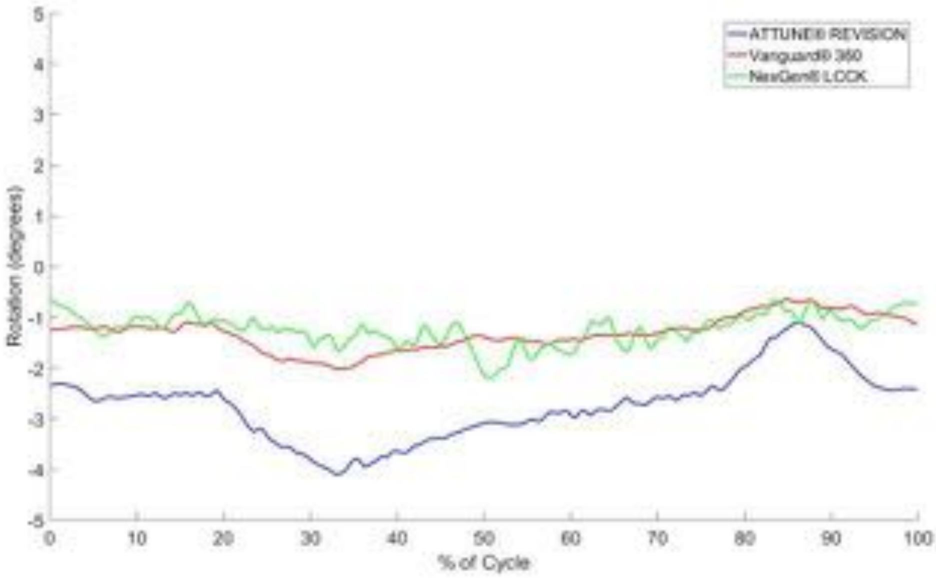

Figure 3: Change in tibiofemoral, IE kinematics during simulated activity. The kinematics from the activity without torque was subtracted from the cycle with torque. The range of change in rotation, averaged across the cycle for knees with an ATTUNE® REVISION implant was 2.38°, for Vanguard® 360 was 0.52°, and for NexGen® LCCK was 0.58°.

Figure 3

#5777

Posterior Loading During Deep Knee Bend: A Critical Biomechanical State for Evaluating Bone Fillers in Revision Total Knee Arthroplasty

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INTRODUCTION

Porous metal bone fillers are frequently used to manage bony defects encountered in revision total knee arthroplasty (rTKA). Compared to structural graft, porous metal bone fillers have shown significantly lower loosening and failure rates potentially due to osseointegration and increased material strength [1]. The strength of porous metal bone fillers used in lower extremities is frequently assessed using compression/shear/torsion test methods, adapted from spine standards. However, these basic methods may lack clinical relevance, and do not provide any insight on the relationship between patient activity and anticipated prosthesis performance. The goal of this study was to evaluate the response of bone fillers under different activities of daily living, in order to define physiologically relevant worst case biomechanics for component evaluation.

METHODS

A bone filler tibial augment is shown in Figure 1. A test construct for tibial augments (half-block each for medial and lateral sides) is shown in Figure 2, along with compatible rTKA components. An additional void in the bone was filled using bone cement. Loading was applied through the tibiofemoral contact patches created on polyethylene tibial insert. Loading was used for two activities of daily living; walking and deep knee bend [2-3]. During walking, the tibiofemoral contact patch on the anterior tibial post gets loaded due to femoral hyperextension with 1.2xbody weight (BW), whereas the medial and lateral condyles get loaded with 3xBW compressive load. For deep knee bend, only the condyles get loaded with 4.34xBW. Compared to walking, 45% higher compressive load magnitude in deep knee bend located further posterior was anticipated to create a larger bending moment and induce higher stress on the half augments. A finite element analysis (FEA) was performed by modeling this test construct with a medium size tibial augment. All components were modeled using linear elastic material properties. All interfaces, including the augment-bone interface (representing full bony ingrowth construct) were modeled using bonded contact. The inferior surface of the bone analogue was constrained. Linear static analyses were performed and peak von mises stress predicted in the tibial augments was compared between activities.

RESULTS

Deep knee bend resulted in 31% higher stresses in the tibial augments than for walking. High von mises stresses were mostly predicted at the superior/posterior aspect of the internal side of the augment and in the corners of the cutouts. Figure 3 presents the von mises stresses in the tibial augments for both loading scenarios.

DISCUSSION

This study revealed that the 45% increased posterior compressive load associated with deep knee bend is a more significant factor than the moment applied to the post during walking gait for a hyperextended knee, when considering the stress in bone filler augments in revision TKA. The stress in the augments can depend on multiple factors and the proposed FEA method can be used to compare stresses in different porous material bone fillers to determine worst case for assessing its strength.

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Figures

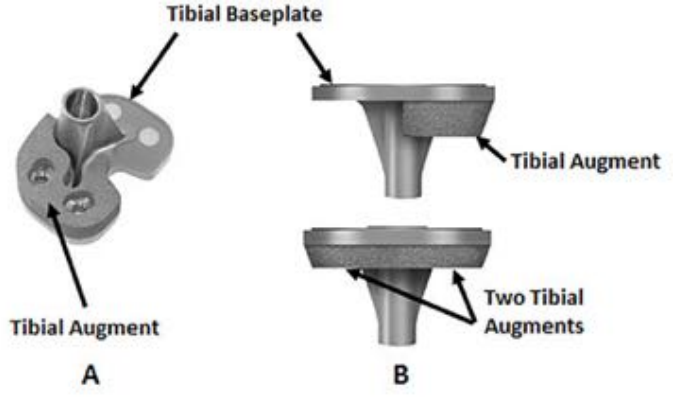

Figure 1. (A) Tibial augment placed underside tibial baseplate. (B) Use of one or two tibial augments

Figure 1

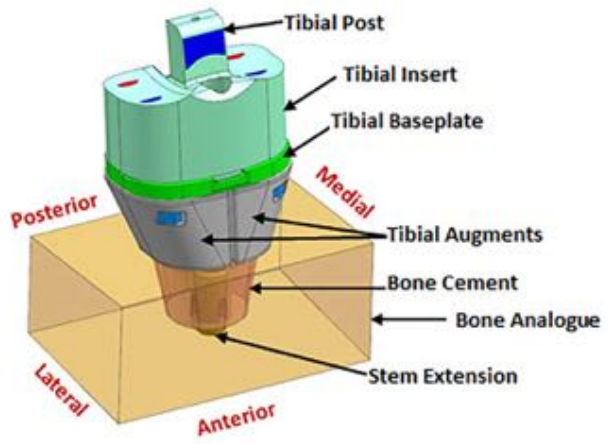

Figure 2. Left knee construct showing activity based load patches on tibial insert: blue patches for walking, red patches for deep knee bend

Figure 2

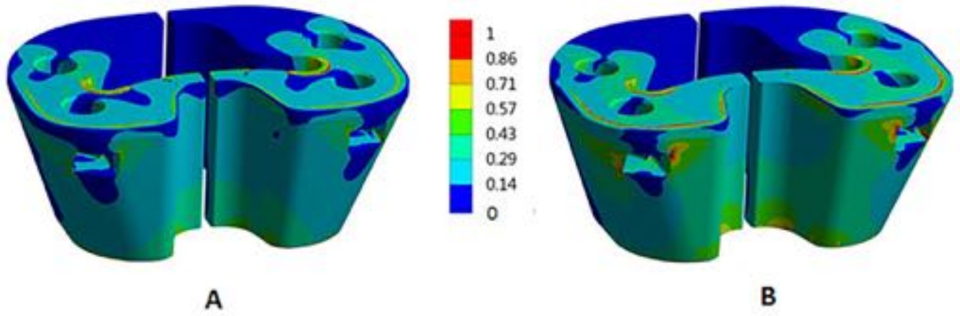

Figure 3. Von mises stress in tibial augments, normalized using the peak stress from deep knee bend activity
(A) Walking (B) Deep Knee Bend

Figure 3

#5762

Influence of Tibiofemoral Contact and Metal Reinforcement on Articular Surface Spine Stresses

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INTRODUCTION

Tibiofemoral contact at the base of the articular surface spine in posterior-stabilized total knee arthroplasty (TKA) implants can lead to spine fracture [1]. Revision TKA implants also have an articular surface spine to provide sufficient constraint when soft tissues are compromised. While some revision TKA designs have metal reinforcement in the articular surface spine, others rely solely on a polyethylene spine. This study used finite element analysis (FEA) to study the effect of metal reinforcement on stresses in the spine when subjected to posteriorly directed loading.

METHODS

Two clinically successful Zimmer Biomet revision TKA designs were selected; NexGen LCCK with metal reinforcement and all-poly Vanguard SSK. The largest sizes were selected. FEA models consisted of the polyethylene articular surface and a CoCr femoral component; LCCK also included a CoCr metal reinforcement in the spine. A 7â° and 0â° tibial slope, as well as 3â° and 0.7â° femoral hyperextension, were used for the LCCK and SSK, respectively. A posteriorly directed load was applied to the spine through the femoral component (Figure 1). The base of the articular surface was constrained. The articular surfaces for both designs are made from different polyethylene materials. However, for the purpose of this study, to isolate the effect of material differences on stresses, both were modeled using conventional GUR1050 nonlinear polyethylene material properties. Femoral component and metal reinforcement were modeled using linear elastic CoCr properties. Additionally, the LCCK was reanalyzed by replacing the metal reinforcement component with polyethylene material, in order to isolate the effect of metal reinforcement for an otherwise equivalent design. Frictional sliding contact was modeled between the spine and femoral/metal reinforcement components. Nonlinear static analyses were performed using Ansys version 17 software and peak von mises stresses in the spine were compared.

RESULTS

Peak von mises stresses were predicted towards the base of the anterior aspect of the spine in both designs (Figure 2). In LCCK, the high stresses were also predicted on the medial and lateral edges of the anterior spine, matching the tibiofemoral contact (Figure 3). The LCCK with metal reinforcement design predicted 14% and 31% lower stress than LCCK and SSK all-poly designs.

DISCUSSION

Clinical reports of spine fracture in TKA highlight the need for further understanding of the biomechanics of spine loading. Here, through comparison of two clinically successful devices, the effect of multiple design factors was quantified. Inclusion of metal reinforcement in the spine, as well as differences in the conforming geometry between the femoral component and the articular surface, resulted in a 31% decrease in polyethylene stress for the LCCK as compared to the all-poly SSK; of which only 16% was attributed to the metal reinforcement. Further improvements to articular surface design, as well as polyethylene material advances, have the potential to result in all-poly designs with strength characteristics equivalent to or exceeding those of designs with metal reinforcement.

REFERENCES

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Figures

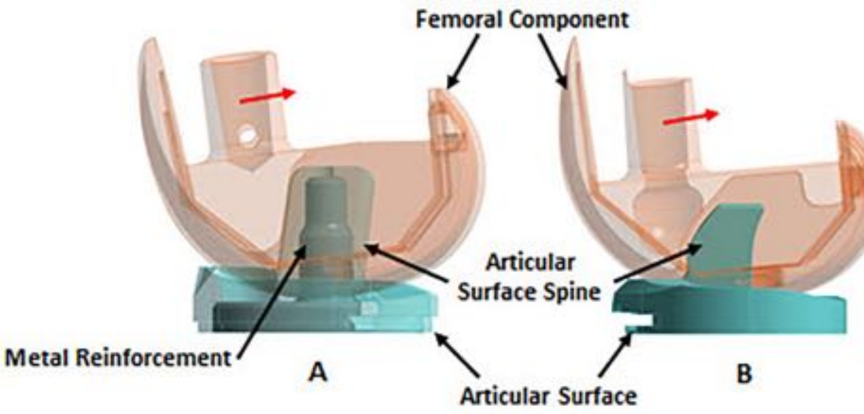

Figure 1. Posteriorly directed load (red arrow)
A. LCCK design with metal reinforcement B. SSK all-poly design
Figure 1

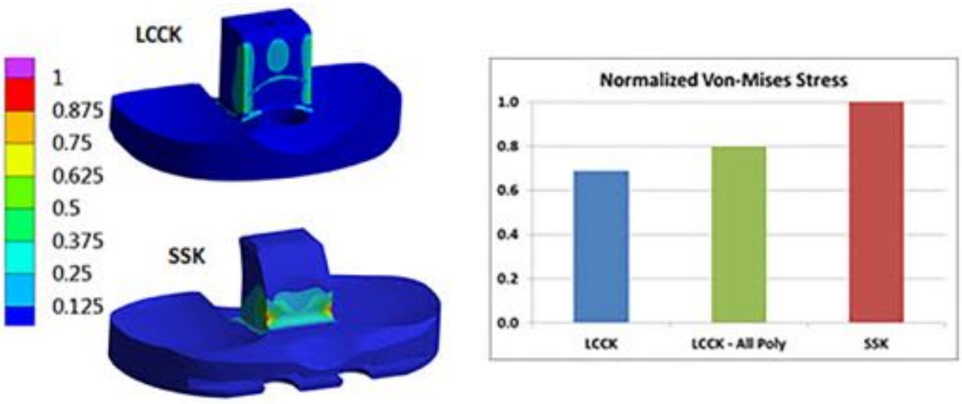

Figure 2. Von Mises Stress (normalized to SSK peak stress)
Figure 2

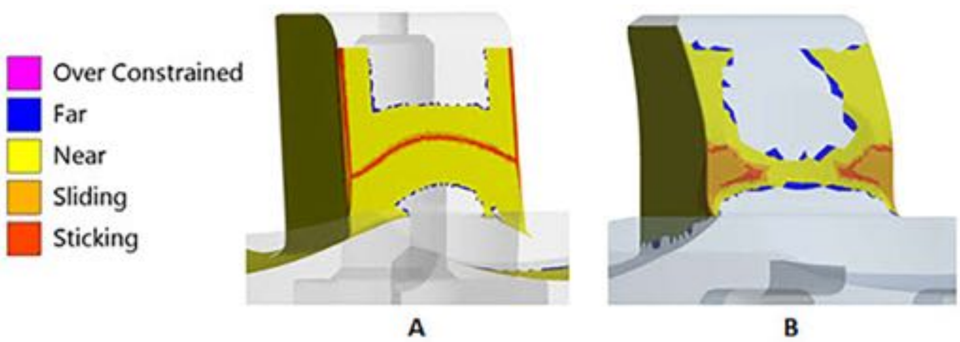

Figure 3. Tibiofemoral contact on anterior articular surface spine
A. LCCK. B. SSK
Figure 3

#5837

Parametric Computational Study of the Effect of Different AORI Defect Types on Primary Stability of Sleeved Revision Tibial Tray With and Without Stem.

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The complexity of revision total knee replacement (rTKR) is highly dependent on the severity of bone loss. The degree of bone loss is usually clinically categorized by the Anderson Orthopaedic Research Institute Classification (AORI) (1), with Type III defect classified as most severe. Approximately, 29% of the revision surgeries are the result of a Type III defect (2-4). Modular implants (sleeves and stems) are used to compensate for bone loss and facilitate for zonal fixation in at least two zones (metaphysis and diaphysis) (3). Porous metaphyseal sleeves have shown early to midterm clinical success (2-4). Interestingly, metaphyseal sleeves have been used alone, without stems (stemless) in AORI Type II and III defect as reported in a short term follow-up clinical review (4). However, the effect of using stemless implants on primary stability and strain distribution in Type III defect is not well understood.In this study, a paramatric computational study investigated the effect of varying the defect type and shape on the primary stability and strain distribution of cementless sleeved revision tibial trays.

An FE model was generated of the non-operated limb of a post TKR 72 year old male patient with body mass index of 25 kg.m^{-2} (weight: 82kg, height: 1.8m). Grey scale values were sampled from CT scan to extract material properties. Hypermesh was utilized to include the patient specific bone defect (AORI Type II caused by removing the previous TKR implant and cement in the contralateral tibia). The revision tibial tray (DePuy ATTUNE® Revision Rotating Platform Knee System) was aligned with the central vertical axis of the intramedullary canal following the surgical guidelines (DePuy Synthes Joint Reconstruction, Warsaw, IN). Hypermesh was then used to include a 25° (AORI Type II), a 50° (AORI Type III), & a 75° (AORI Type III) wedge defect on one condyle (Figure 1A). In addition, a 15° (AORI Type II), a 30° (AORI Type III), & a 45° (AORI Type III) wedge defect was included covering both condyles (Figure 1B). These defects were included to the medial, lateral, anterior, and posterior sides of the tibia. Joint contact forces for stair descent were applied using data from musculoskeletal modelling.

Although stemless sleeved implants achieved primary stability in this simulation of certain specific AORI Type II defects, in AORI Type III defects a stem that engages the intramedullary canal was required. In addition, in AORI Type III defects, a stemless implant had an elevated composite peak microstrain (CPS) compared to a stemmed implant. This elevated strain was correlated with decreased contact surface area (Figure.2). The outcome suggest that, under the given conditions of this study in an AORI Type III defect, a stem would be required for the implant to reach primary stability.

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Figures

Figure 1

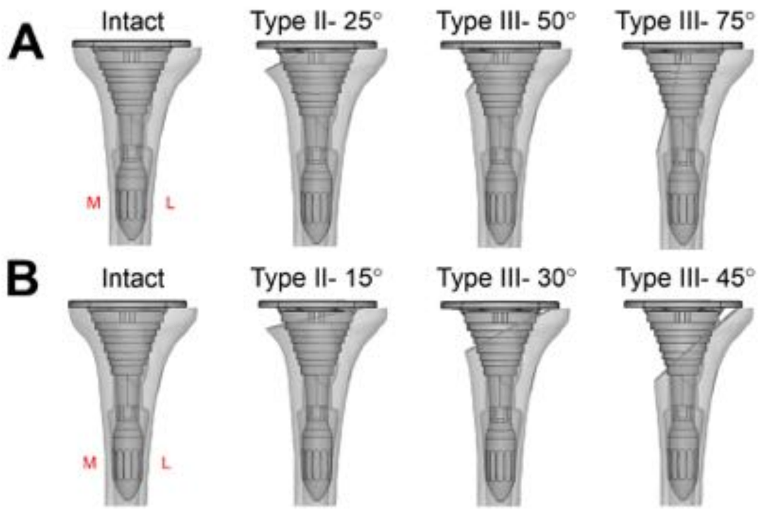

Figure 1

Figure 2

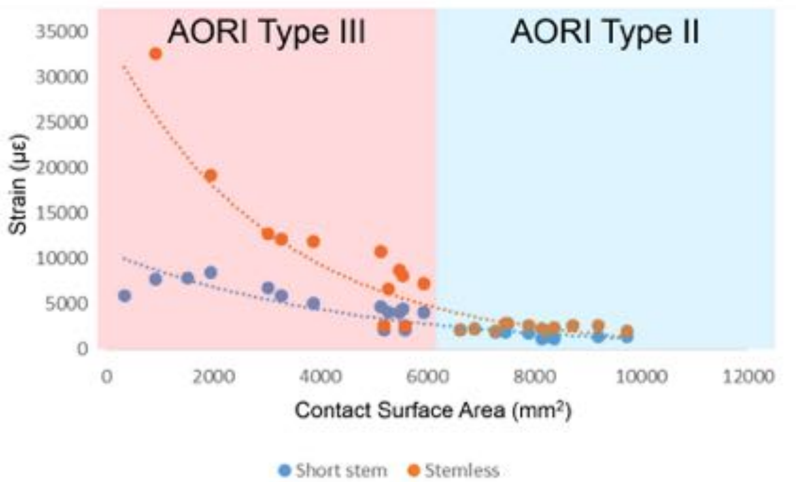

Figure 2

#5765

The Walch B2 Humerus: Glenoid Retroversion Is Associated With Torsional Differences in the Humerus

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Introduction

The Walch Type B2 glenoid has the hallmark features of posteroinferior glenoid erosion, retroversion, and posterior humeral head subluxation. Although our understanding of the pathoanatomy of bone loss and its evolution in Type B's has improved, the etiology remains unclear. Furthermore, the morphology of the humerus in Walch B types has not been studied. The purpose of this imaging based anthropometric study was to examine the humeral torsion in Walch Type B2 shoulders. We hypothesised that there would be a compensatory decrease in humeral retroversion in Walch B2 glenoids.

Methods

Three-dimensional models of the full length humerus were generated from computed tomography data of normal cadaveric (n = 59) and Walch Type B2 shoulders (n = 59). An anatomical coordinate system referencing the medial and lateral epicondyles was created for each model. A simulated humeral head osteotomy plane was created and used to determine humeral version relative to the epicondylar axis and the head-neck angle. Measurements were repeated by two experienced fellowship-trained shoulder surgeons to determine inter-rater reliability. Glenoid parameters (version, inclination and 2D critical shoulder angle) and posterior humeral head subluxation were calculated in the Type B2 group to determine the pathologic glenohumeral relationship. Two-way ANOVAs compared group and sex within humeral version and head-neck angle, and intra-class correlation coefficients (ICCs) with a 2-way random effects model and absolute agreement were used for inter-rater reliability.

Results

There were statistically significant differences in humeral version between normal and B2 shoulders ($p < .001$) and between males and females within the normal group ($p = .043$) (Figure 1). Normal shoulders had a humeral retroversion of 36±12°, while the Walch B2 had a humeral retroversion of 14±9° relative to the epicondylar axis. For head-neck angle, there were no significant differences between sexes ($p = .854$), or between normal and B2 shoulders when grouped by sex ($p = .433$). In the Type B2 group, the mean glenoid version was 22±7°, glenoid inclination was 8±6°, 2D critical shoulder angle was 30±5° and humeral head subluxation was 80±9%. Inter-rater reliability showed fair agreement between the two experienced observers for head-neck angle (ICC = .562; 95% CI: -.28 to .809) and excellent agreement for humeral version (ICC = .962; .913 to .983). Although only fair agreement was found between observers in head-neck angle ICC, the difference in mean angle was only 2°.

Discussion

Although much time and effort has been spent understanding and managing B2 glenoids, little attention has been paid to investigating associated humeral contributions to the B2 shoulder. Our results indicate that the humeral retroversion in type B2 shoulders is significantly lower than in normals. These findings have several implications, including, helping to understanding the etiology of the B2, the unknown effects of arbitrarily selecting higher version angles for the humeral component, and the unknown effects of altered version on glenohumeral joint stability, loading and implant survivorship post-arthroplasty. Our results also raise an important question, whether it is best to reconstruct B2 humeral component version to pathologic version or to non-pathologic population means.

Figures

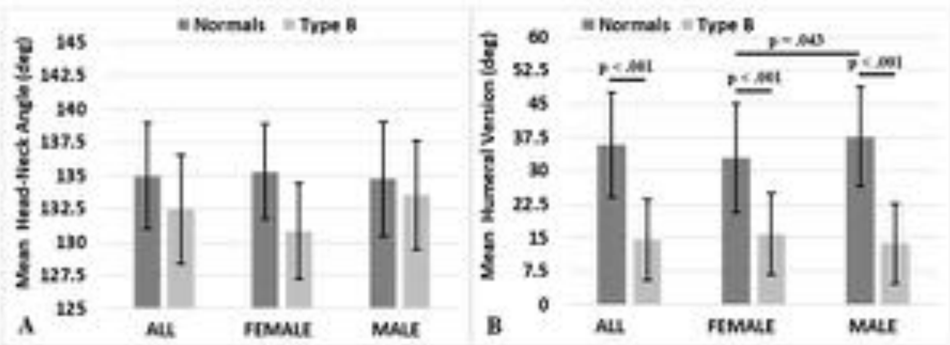

Figure 1: Mean parameters for all shoulders, females, and males. The head-neck angle **(A)** and humeral version **(B)**. Comparison for all shoulders (n=59) were completed with t-tests, and male (n=36) female (n=23) comparisons using two-way ANOVAs with sex and group as factors.

Figure 1

#5648

Navigated vs. Non-Navigated Results of a CT Based Computer Assisted Shoulder Arthroplasty System in 30 Cadavers

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INTRODUCTION:

Variability in placement of total shoulder arthroplasty (TSA) glenoid implants has led to the increased use of 3D CT preoperative planning software. Computer assisted surgery (CAS) offers the potential of improved accuracy in TSA while following a preoperative plan, as well as the flexibility for intraoperative adjustment during the procedure. This study compares the accuracy of implantation of reverse total shoulder arthroplasty (rTSA) glenoid implants using a CAS TSA system verses traditional non-navigated techniques in 30 cadaveric shoulders relative to a preoperative plan from 3D CT software.

METHODS:

High resolution 1mm slice thickness CT scans were obtained on 30 cadaveric shoulders from 15 matched pair specimens. Each scan was segmented and the digital models were incorporated into a preoperative planning software. Five fellowship trained orthopedic shoulder specialists used this software to virtually place a rTSA glenoid implant as they deemed best fit in six cadavers each. The specimens were randomized with respect to side and split into a cohort utilizing the CAS system and a cohort utilizing conventional instrumentation, for a total of three shoulders per cohort per surgeon. A $BaSO_4$ PEEK surrogate implant identical in geometry to the metal implant used in the preoperative plan was used in every specimen, to maintain high CT resolution while minimizing CT artifact. The surgeons were instructed to implant the rTSA implants as close to their preoperative plans as possible for both cohorts. In the CAS cohort, each surgeon used the system to register the native cadaveric bones to each respective CT, perform the TSA procedure, and implant the surrogate rTSA implant. The surgeons then performed the TSA procedure on the opposing side of the matched pair using conventional instrumentation. Postoperatively, CT scans were repeated on each specimen and segmented to extract the digital models. The pre- and postoperative scapulae models were aligned using a best fit match algorithm, and variance between the virtual planned position of the implant and the executed surgical position of the implant was calculated [Fig 1].

RESULTS:

For version and inclination, implants in the CAS cohort showed significantly less deviation from preoperative plan than those in the non-navigated cohort (Version [Fig 2]: 1.9 ± 1.9° vs 5.9 ± 3.5°; $p < .001$; Inclination [Fig 3]: 2.4 ± 2.5° vs 6.3 ± 6.2°; $p = .031$). No significant difference was noted between the two cohorts regarding deviation from the preoperative plan in anterior-posterior and superior-inferior positioning on the glenoid face (1.5 ± 1.0mm CAS cohort, 2.4 ± 1.3mm non-navigated cohort; $p = .055$).

No significant difference was found for deviation from preoperative plan for reaming depth (1.1 ± 0.7mm CAS cohort, 1.3 ± 0.9mm non-navigated cohort; p =.397).

CONCLUSION:

The results of this study demonstrate that this CAS navigation system facilitates a surgeon's ability to more accurately reproduce their intended glenoid implant version and inclination (with respect to their preoperative plan), compared to conventional non-navigated techniques. Future work will determine if more accurate and precise implant placement is associated with improved clinical outcomes.

Figures

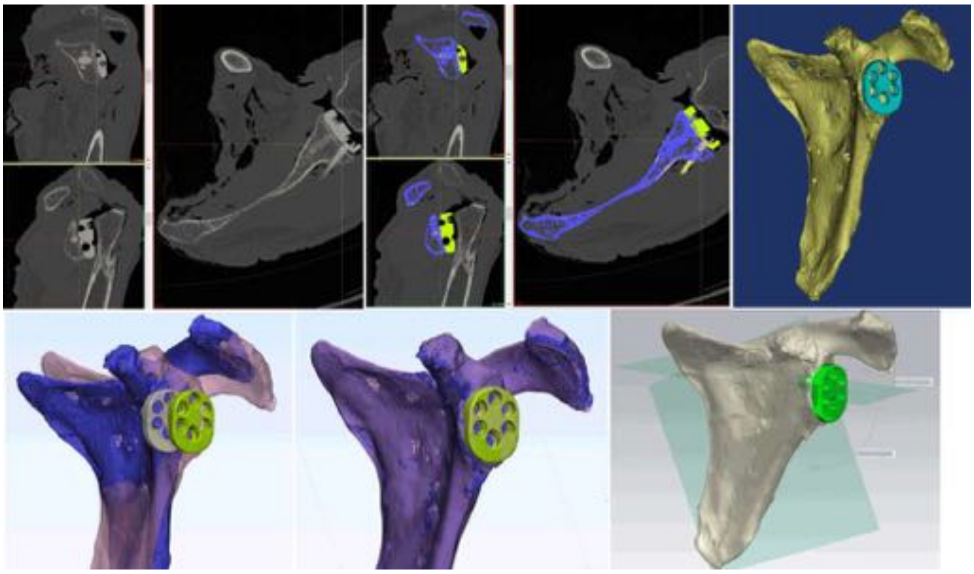

Figure 1

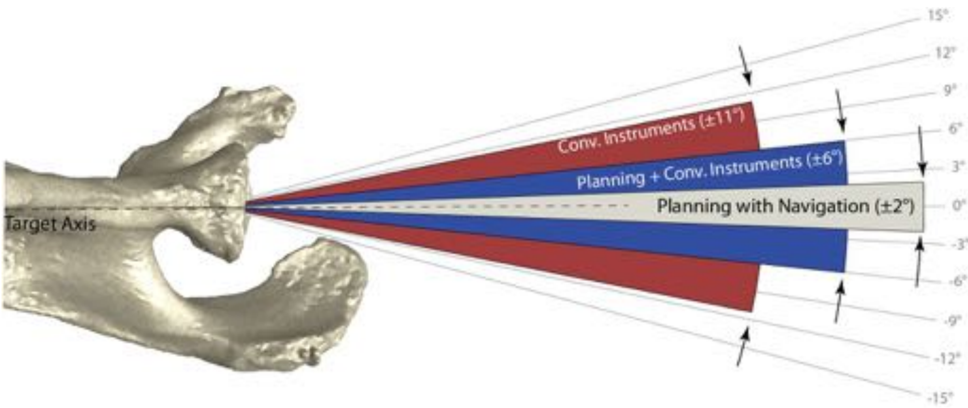

Figure 2

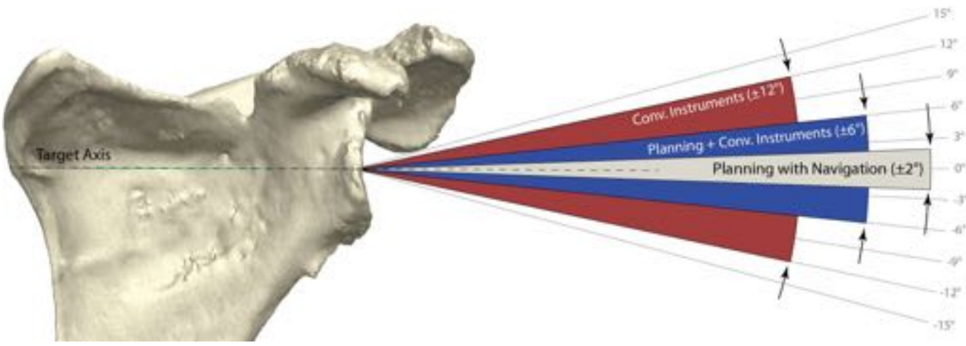

Figure 3

#5610

Edge Loading Properties of Glenoids Articulating Against a Ceramic Humeral Head: Comparative Wear Study of Conventional and Highly Cross-Linked Vitamin E Polyethylene

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Introduction:

Polyethylene wear resulting in glenoid loosening is the main reason for long-term failure of total shoulder replacement [1]. This study was done to compare the wear behaviour under edge loading of a ceramic humeral head on conventional polyethylene (CPE) glenoid components and vitamin E enhanced highly cross-linked (VEPE) polyethylene glenoids.

Methods:

Wear tests were performed using a shoulder wear simulator set up for roll-glide with edge loading of ±1.5 mm, analogue to ISO 14243-1 and 14243-2. The tests were run for 0.5 million cycles (Mc) at IMA GmbH Dresden, Germany. Commercial, sterilised implants from the Affinis® Shoulder System were tested (Mathys Ltd Bettlach, Switzerland). All test cohorts used size 51/19 Affinis® ceramic (Al_2O_3) humeral heads. On the glenoid side Affinis® components size 4 were used, in CPE and VEPE. The vitamin E enhanced highly cross-linked PE by Mathys, trade name vitamys®, is manufactured from GUR 1020 UHMWPE and contains 0.1% blended Vitamin E. Glenoids in non-aged condition and with accelerated ageing according ASTM F2003 (pure oxygen at 5 bar and 70 °C for 14 days) were compared. The wear was assessed gravimetrically. Photo-optical documentation of the worn surfaces were completed on all specimens before, and at the conclusion of testing.

Results:

The unaged VEPE glenoid showed a wear rate of 9.97±0.95 mg/Mc, a 36% reduction compared to the unaged CPE glenoid with 15.54±2.08 mg/Mc (Figure 1). Ageing significantly increased the polyethylene wear rate, 26.44±3.01 mg/Mc for CPE and 13.61±1.37 mg/Mc for VEPE (Figure 1). Compared to the corresponding unaged cohorts, both aged cohorts demonstrated increased wear rates after artificial aging. However, the advantage of VEPE over CPE is more pronounced with a 49% reduction in wear in the VEPE group (Figure 1). The optical appearance after the test showed no signs of wear on the ceramic heads and typical wear patterns on the glenoid components. On the articulating surfaces of the glenoids, the transition between loaded and unloaded regions was clearly visible. Evidence of wear around the rim of the prosthesis confirmed that edge loading had occurred during the simulation. No back-side wear was observed.

Discussion & Conclusion:

The distinct worst-case edge loading on the rim of the glenoids did not lead to abnormal wear behaviour for any group of implants. However, this study demonstrates in vitro superior wear properties of the VEPE glenoid compared to conventional polyethylene when articulating with a ceramic head under edge loading conditions. The addition of vitamin E to polyethylene was shown to decrease polyethylene degradation related to oxidation [2], resulting in less wear in the artificially aged VEPE glenoid compared to the corresponding CPE component.

References:
[1] Matsen FA et al. (2008), J Bone Joint Surg Am**90**:885-96
[2] Lerf R et al. (2010), Biomaterials **31**:3643–48

Figures

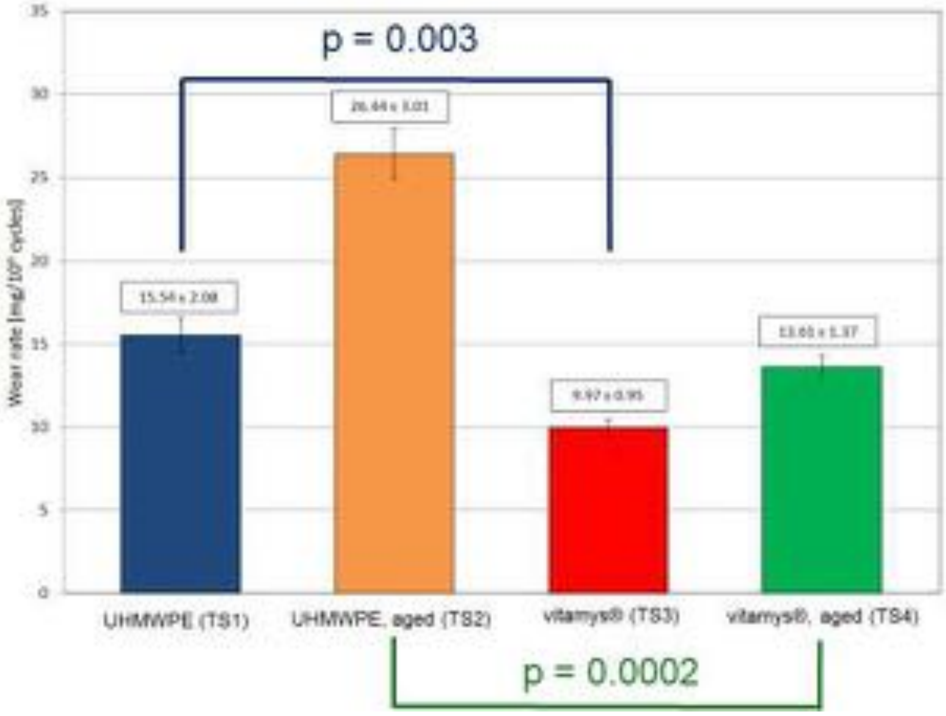

Figure 1

Minimally Invasive Total Shoulder Arthroplasty Using a Novel Patient Specific Guide and Instrumentation System: A Cadaveric Validation

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PURPOSE: To validate the efficacy and accuracy of a novel patient specific guide (PSG) and instrumentation system that enables minimally invasive (MI) short stemmed total shoulder arthroplasty (TSA).

MATERIALS AND METHODS: Using Amirthanayagam et al.'s (2017) MI posterior approach reduces incision size and eliminates subscapular transection; however, it precludes glenohumeral dislocation and the use of traditional PSGs and instruments. Therefore, we developed a PSG that guides trans-glenohumeral drilling which simultaneously creates a humeral guide tunnel/working channel and glenoid guide hole by locking the bones together in a pre-operatively planned pose and drilling using a c-shaped drill guide (Figure 1). To implant an Affinis Short TSA system (Mathys GmbH), novel MI instruments were developed (Figure 2) for: humeral head resection, glenoid reaming, glenoid peg hole drilling, impaction of cruciform shaped humeral bone compactors, and impaction of a short humeral stem and ceramic head.

The full MI procedure and instrument system was evaluated in six cadaveric shoulders with osteoarthritis. Accuracy was assessed throughout the procedure: 1) PSG physical registration accuracy, 2) guide hole accuracy, 3) implant placement accuracy. These conditions were assessed using an Optotrak Certus tracking camera (NDI, Waterloo, CA) with comparisons made to the pre-operative plan using a registration process (Besl and McKay, 1992).

RESULTS: 3D translational accuracy of PSG physical registration was: humeral PSG- 2.2 ± 1.1 mm and scapula PSG- 2.5 ± 0.7 mm. The humeral and scapular guide holes had angular accuracies of 6.4 ± 3.2° and 8.1 ± 5.1°, respectively; while the guide hole positional accuracies on the articular surfaces (which will control bone preparation translational accuracy) were 2.9 ± 1.2 mm and 2.8 ± 1.3 mm. Final implantation accuracy in translation was 2.9 ± 3.0 mm and 5.7-6.8 ± 2.2-4.0° across the implants' three rotations for the humerus and in translation was 2.8 ± 1.5 mm and 2.3-4.3 ± 2.2-4.4° across the implants' three rotations for the scapula (Figure 3).

DISCUSSION: The overall implantation accuracy was similar to results of previously reported open, unassisted TSA (3.4 mm & 7-12°, Hendel et al., 2012, Nguyen et al., 2009). Analysis of the positional PSG registration accuracy very closely mirrors the final implantation accuracy (humerus:2.2 mm vs 2.9 mm, and scapula:2.2 mm vs 2.8mm), thus, this is likely the primary predictor of implantation accuracy. Furthermore, the greatest component of PSG registration error was mediolateral translation (i.e. along the guiding axis) and thus should not affect guide hole drilling accuracy.

The drilled guide hole positional and angular error was low for the humerus (2.9 mm and 6.4°) but somewhat higher in rotation (8.1°) for the glenoid which may indicate a slight shift in the PSG prior to guide hole drilling due to the weight of the arm applied when the PSGs are locked together.

In conclusion, this work has detailed the step-by-step surgical errors associated with the developed system and demonstrated that it achieves similar accuracy to open, unassisted TSA, while avoiding complications related to muscular transection and dislocation. Therefore, we believe this technique is worthy of clinical investigation.

Figures

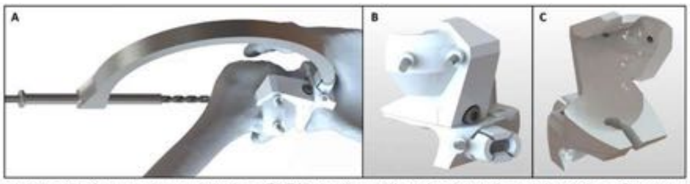

Figure 1: (A) PSI and drill guide for trans-humeral drilling, (B) PSI showing drill guide adapter & modular design, (C) contoured surfaces of PSI.

Figure 1

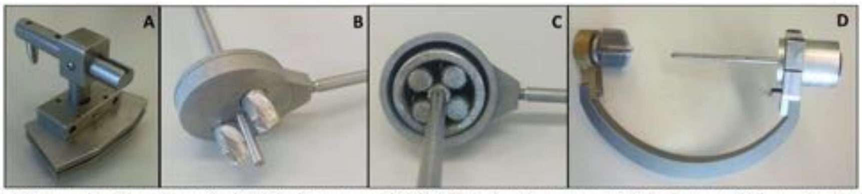

Figure 2: (A) Humeral head resection guide, (B & C) planetary gear drill for Affinis glenoid component, (D) slap hammer with humeral cutter attached.

Figure 2

Figure 3: Computer renderings of final implantation accuracy. The 1st & 4th columns provide references for the location of the implants within the scapula and humerus, respectively. The remaining columns illustrate translational and rotational errors along/about the axes listed. Each image shows the pre-operatively planned position (white implant), the average error across all specimens (blue implant), and the average error + 2 standard deviations (yellow implant) to show the 95% confidence interval.

Figure 3

#5726

Using Finite Element Simulation for ASTM F2028 Reverse Glenoid Loosening

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INTRODUCTION

Assessment of glenoid component loosening in reverse shoulder arthroplasty is described in ASTM F2028-14 [1], which consists of two distinct test phases: a) a cyclic test where the glenoid component is rotated about the humeral liner under a 750N axial compressive load, b) a pre- and post-cyclic displacement test where baseplate edge displacements are measured under static 430N compressive and 350N shear loads.

The purpose of this study was to identify what meaningful information can be gained from finite element (FE) modeling of these two test phases.

METHODS

An inferiorly offset glenosphere, a curved-back baseplate with a central post and two screws were virtually implanted in a foam block (Fig.1) and ASTM F2028-14 [1] was simulated using ANSYS.

All implant connections were bonded. Frictional contacts were defined between the screws/baseplate and the bone substitute. All constituting materials were defined as linear elastic.

The bone substitute was held fixed (Fig.1). Loading occurring during the cyclic test was simulated by applying the 750N load at ±45° in 15° steps in the SI plane. The displacement test was simulated with a 554N force applied at a 39° angle (arctan(350/430)). Edge displacements (resultant of shear and compressive) and peak micromotion at the whole baseplate-foam interface were measured per ASTM F2028.

RESULTS

Lower magnitudes of edge displacements and micromotion were seen in the displacement test step compared to the 45° load (Fig.2/3).

An increase of up to 60% micromotion was found between the 30 and 45° load orientation (Fig.3).

Peak edge displacement and micromotion were consistently found with the most extreme superior and inferior loading angle (45°). For any given angle, the superior direction led to the highest edge displacements, probably due to the glenosphere offset.

DISCUSSION

Peak edge displacements and micromotion values were found at the extreme angle of motion (45°), and both magnitudes were higher than those measured in the displacement test. Therefore, worst case scenario micromotion measurements would be more appropriate during the cyclic test (identified as the daily life simulation part of the test in the ASTM standard) if these were to be compared with micromotion levels for biologic ingrowth (e.g. 150 microns), as values are lower in the displacement test.

The load angle played a tremendous role, with up to 60% micromotion increase by rotating the baseplate from 30 to 45°. This should be kept in mind when comparing results from studies with different loading ranges.

The same worst case testing direction (Superior vs Inferior) was identified in the cyclic and displacement tests, for any simulated load angle, indicating that modeling one superior and inferior load angle would allow identifying the worst case test direction. Similarly, edge displacements may be directly measured during the physical cyclic test, as the ranking is consistent with the displacement test.

Limitations include that fixation deterioration and dynamic effects were not modeled. Conclusions from this study need to be confirmed experimentally and with different implant designs and sizes.

REFERENCES

[1] ASTM F2028-14 -Standard Test Methods for Dynamic Evaluation of Glenoid Loosening or Disassociation, 2014.

Figures

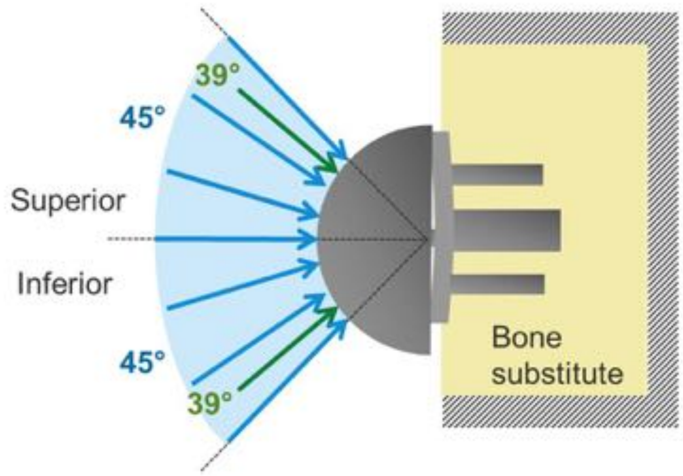

Figure 1: *Schematic representation of the set up. The bone substitute was held fixed in all directions (grey hatching) and the 750N load vector (blue) applied from 0 to 45° in 15° steps to simulate cyclic loading. For the displacement test, a 554N load (green) was applied at 39°.*

Figure 1

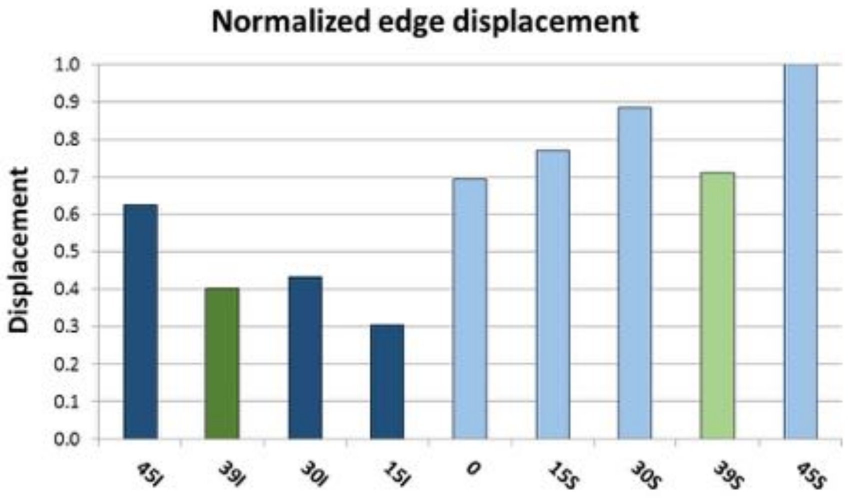

Figure 2. *Influence of loading on edge displacement, normalized with respect to the highest value. On the horizontal axis, the number represents the force angle, S stands for Superior, I for Inferior. Edge displacement values correspond to the resultant displacement of the glenoid component in the shear and axial directions. Bars in green tones correspond to simulation of displacement step.*

Figure 2

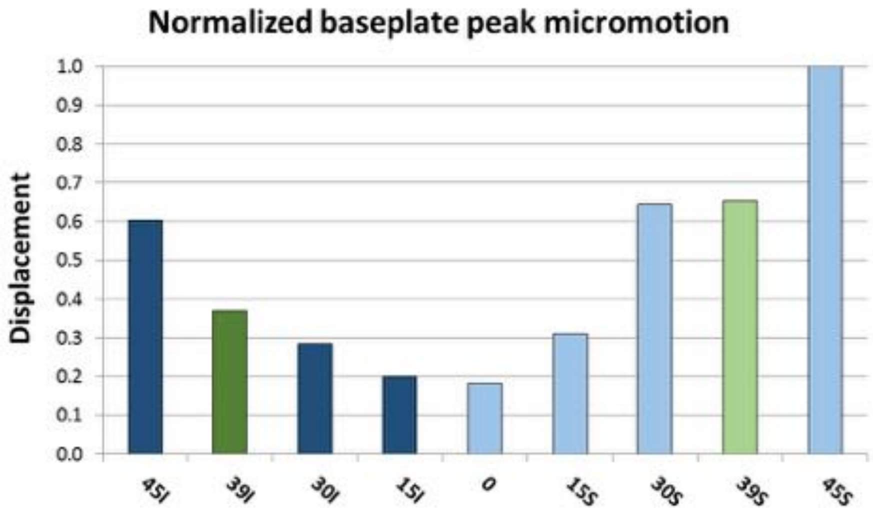

Figure 3. *Influence of loading on peak micromotion, normalized with respect to the highest value. On the horizontal axis, the number represents the force angle, S stands for Superior, I for Inferior. Bars in green tones correspond to simulation of displacement step.*

Figure 3

#5958

Computer-Assisted Total Knee Arthroplasty Improves Patient Reported Outcomes

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Introduction: Total joint arthroplasty is regarded as a highly successful procedure. However, patient outcomes and implant longevity require proper alignment and prosthesis position. Computer-assisted total knee arthroplasty (TKA) has been found to improve the accuracy of component positioning and reduce rates of revision, however there remains debate whether it provides improvements in patient reported outcomes (PROs). The purpose of our study was to compare PROs between computer-assisted and conventional TKA.

Methods: A retrospective review of all total knee arthroplasty patients was conducted using a single institution's FORCE database for reporting PROs. Knee Society Score (KSS), procedure satisfaction, physical component summary (PCS), and mental component summary (MCS) were compared between computer-assisted TKA and conventional TKA.

Results: Computer-assisted TKA had a higher average KSS (68.8 vs 44.6), PCS (33.8 vs 30.4), and MCS (51.1 vs 47.5) compared to conventional TKA. The average procedural satisfaction (4.0 vs 4.2) was equivalent between computer-assisted and conventional TKA, respectively.

Discussion: Computer-assisted TKA improves patient reported outcomes while providing equivalent satisfaction compared to conventional TKA.

#5998

Aim Small, Miss Small: Radiographic and Functional Outcomes of Robotic-Assisted Total Knee Arthroplasty at One Year

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Background: Robotic total knee arthroplasty (TKA) has emerged as a patient specific tool that assists in preoperative planning and surgical execution facilitating fewer outliers and improving alignment accuracy. While haptically guided robotic-assisted TKA holds the promise of enhanced component positioning, the ability to place the components precisely at the planned position is paramount to kinematics and balancing, and only a few studies with small cohorts have examined patient satisfaction and outcomes. In order to invstigate this new TKA robotic-assisted technology and surgical technique, we aim to report the one year results of a large cohort to analyze: (1) discrepancy between preoperative planned and one year follow-up implant inclination in both coronal and sagittal planes; (2) subjective clinical outcome improvement from pre-operative to one year post-operatively.

Methods: Prospectively, data was reviewed for 105 patients who underwent a robotic-assisted TKA using a CT-based haptically guided robotic system from August 2016-April 2017. All patients included had hip-to-ankle standing biplanar EOS radiographs preoperatively and 1 year postoperatively. Independently, two fellowship trained arthroplasty surgeons measured coronal and sagittal alignment of the tibial component and coronal alignment of the femoral component relative to the mechanical axis of the limb on the 1 year postoperative radiographs. These values were then compared to the final intra-operative plan and for inter-observer reliability. The following subjective patient outcome measures were taken preoperatively and at one year follow-up: Levels of Emotional Awareness Score (LEAS), Numeric Pain Rating Scale (NPRS), and Knee Injury and Osteoarthritis Score Junior (KOOS Jr).

Results: In our cohort, the average age was 63.66±8.5 years (Range 51-82) and the average BMI was 29.89± 5.20 kg/m^2. The preoperative template component size was 100% accurate for both components. The absolute mean deviation in postoperative coronal alignment compared to intraoperative alignment was 0.625±0.70° and 0.45 ±0.50° for the tibia and femur respectively. The absolute mean change in postoperative tibial sagittal alignment was 0.47±0.76°. Interobserver reliability was significant between both observers (p<0.05). Preoperative and one year subjective measures were: LEAS 8, 10; NPRS 8, 1; KOOS Jr 78, 84.6 **p<0.05.**

Conclusion:To our knowledge, this is the largest robotic-assisted TKA cohort described, as well as the first to juxtapose intra-operative alignment plan to one year follow-up alignment. The haptically guided robotic-arm-assisted TKA demonstrated high reliability and accuracy of coronal tibial, coronal femoral, and tibial sagittal alignment when comparing the executed intraoperative plan at 1 year post-operative via biplanar hip-to-ankle radiographs. It also allowed for accurate pre-operative templating of implant sizes. Patients report high subjective clinical outcome score improvement at one year.

Haptically guided robotic-assisted technology can accurately and reproducibly align TKA at one year with excellent patient satisfaction. The potential of this new surgical technique is promising with excellent one year results, and long term follow-up studies may further extract the clinical advantage of improved alignment, decreased outliers, and the ability to place implants precisely.

#5820

Less Iatrogenic Soft Tissue Damage in Robotic Assisted Haptically Guided Total Knee Arthroplasty When Compared With Manual Approach

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Introduction: While manual total knee arthroplasty (MTKA) procedures have demonstrated excellent clinical success, occasionally intraoperative damage to soft tissues can occur. Robotic-arm assisted technology is designed to constrain a sawblade in a haptic zone to help ensure that only the desired bone cuts are made. The objective of this cadaver study was to quantify the extent of soft tissue damage sustained during TKA through a robotic-arm assisted (RATKA) haptically guided approach and conventional MTKA approach.

Methods: Four surgeons each prepared six cadaveric legs for CR TKA: 3 MTKA and 3 RATKA, for a total of 12 RATKA and 12 MTKA knees. Two independent surgeons graded the damage of 14 knee structures: dMCL, sMCL, posterior oblique ligament (POL), semi-membranosus muscle tendon (SMT), gastrocnemius muscle medial head (GMM), PCL, ITB, lateral retinacular (LR), LCL, popliteus tendon, gastrocnemius muscle lateral head (GML), patellar ligament, quadriceps tendon (QT), and extensor mechanism (EM). Damage was defined as tissue fibers that were visibly torn, cut, frayed, or macerated. Percent damage was averaged between evaluators, and grades were assigned: Grade 1) complete soft tissue preservation to ≤5% damage; Grade 2) 6 to 25% damage; Grade 3) 26 to 75% damage; and Grade 4) 76 to 100% damage. A Wilcoxon Signed Rank Test was used for statistical comparisons. A p-value <0.05 was considered statistically significant.

Results: Significantly less damage occurred to the PCL in the RATKA than the MTKA specimens (p=0.004), [Fig. 1]. Examples of arthroscope images of severed PCL and intact PCL, from MTKA and RATKA specimens, respectively, are seen in Fig. 2. RATKA specimens had less damage to the dMCL (p=.186), ITB (p=0.5), popliteus (p=0.137), and patellar ligament (p=0.5). The sMCL, POL, SMT, GMM, GML, LR, LCL, QT, and EM were grade 1 in all MTKA and RATKA specimens. No intentional soft tissue releases were performed in either group to balance the knee.

Discussion/Conclusion: The results of this study indicate that RATKA may result in less soft-tissue damage than MTKA, especially to the PCL. This finding can potentially be attributed to RATKA using a stereotactic boundary to constrain the sawblade, which can prevent unwanted soft-tissue damage. However, since any damage was post-operatively assessed and in a cadaveric model, further investigations on soft-tissue damage from patients with clinical outcomes should be performed.

Figures

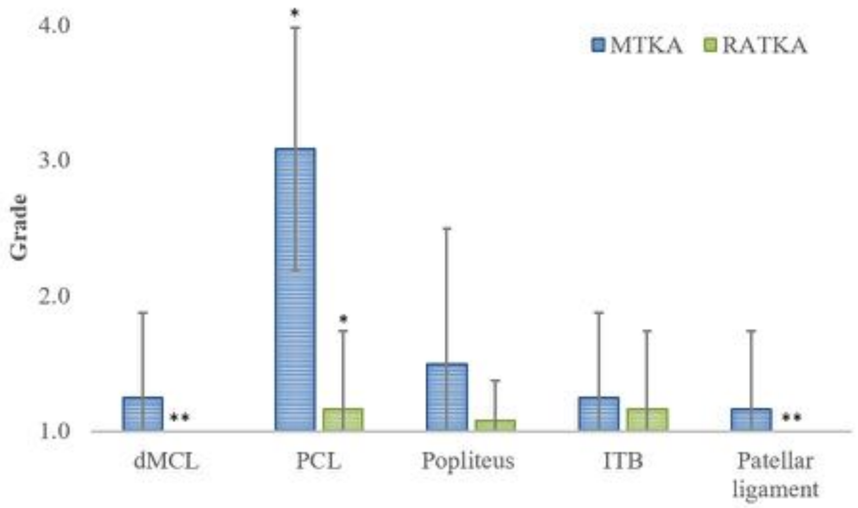

Figure 1. Bar chart showing the average Grade 1-4 damage for the dMCL, PCL, popliteus, ITB, and patellar ligament in MTKA and RATKA specimens. Error bars indicate standard deviations. *PCL showed significant difference ($p<0.05$). **Grade average ± standard deviation for dMCL and patellar ligament was 1±0.

Figure 1

Figure 2: Example arthroscope images of a) severed PCL and b) intact PCL, from MTKA and RATKA specimens, respectively.

Figure 2

#5651

The Learning Curve of Robotic Arm Assisted (RAA) Total Knee Arthroplasty a Prospective Evaluation and CUSUM Analysis

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Introduction & Aims

Robotic Arm Assisted Total Knee Arthroplasty is the leading application of Orthopaedic robotic surgery. As a result of the novelty of this surgical technology its learning curve remains ill defined. This study aims to identify various learning curve transition points, using Cumulative Summation (CUSUM) analysis and to assess whether the learning curve differs between surgeons with a background using either conventional instruments or computer navigation.

Methods

Information regarding all Robotic Arm Assisted TKA's performed by the 2 lead authors were prospectively collected between December 2016 and March 2018. Time based surgical process outcomes were evaluated, as well as clinical outcomes. Time points measured included, In to Operating Theatre (OT), Anaesthetic Start Time (ST), Surgery ST, Saw Cut ST, Saw Cut complete, Implants opened, Final implants placed, Surgery complete, Anaesthetic complete, Out of Theatre time, Total Surgical Time and Total Theatre Time. Prior to commencing Robotic TKA, surgeon 1 used conventional instruments whilst surgeon 2 used computer navigation.

Other factors influencing increased timings were also noted.

Results

Three hundred Robotic Arm Assisted Total Knee Arthroplasties were performed by both lead authors during the study duration. Data was available for 293 of these. A further 24 cases were excluded due to malfunctions of the robotic arrays, saw attachment issues, registration issues, implant problems and surgical complications, leaving a cohort of 269 cases. Twelve time points noted above were recorded and sub-classified into Total Theatre Time, Total Anaesthetic Time and Total Surgical Time. Surgical time only was used for Cumulative Summation analysis.

The CUSUM chart seen in graph 1, highlights a biphasic learning curve, with an inflection point at patient 52. From here on, the CUSUM for surgical time continued to decline, and was persistently less than the target time at patient 90. It was also noted that there was a steep learning curve for the first 21 patients, where the CUSUM value continued to rise.

In comparison to Surgeon 1, the CUSUM chart for surgeon 2 can be seen in graph 2. Here was see that the learning curve was multiphasic, with multiple inflection points. The total surgical time began to continually decrease after patient 100. It is also worth noting that between patient 34 and 82, the CUSUM surgical time was always less than the target surgical time.

As can be seen from the tables there was a significant reduction in mean surgical time when comparing the first 20 cases and the last 20 cases for each surgeon ($p<0.05$)

Conclusion

This study identiï¬ed numerous well-deï¬ned learning curve trends to afï¬rm that experience confers signiï¬cant temporal improvements. Our ï¬ndings highlight the value of the CUSUM method for learning curve evaluation.

Figures

Surgeon 1	Surgery 1-20	Surgery 93-112	P Value
Mean Surgical time	135.25	115.9	<0.05
Standard Deviation	17.7967324	12.26848766	

Plot Area

Surgeon 2	Surgery 1-20	Surgery 105-124	P Value
Mean Surgical time	120.65	103.8	<0.05
Standard Deviation	16.06327947	13.74810992	

Figure 1

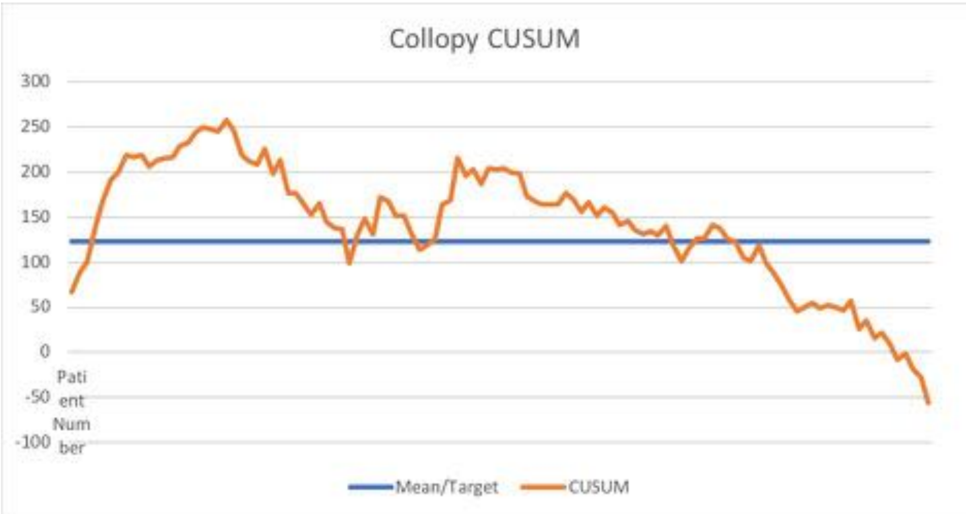

Figure 2

Figure 3

Wear Analysis of 1385 Tibial Inserts: What Factors Are Driving Performance?

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Introduction

Wear of polyethylene tibial inserts has been cited as being responsible for up to 25% of revision surgeries, imposing a very significant cost burden on the health care system and increasing patient risk. Accurate measurement of material loss from retrieved knee bearings presents difficult challenges because gravimetric methods are not useful with retrievals and unworn reference dimensions are often unavailable. Geometry and the local anatomy restrict in vivo radiographic wear analysis, and no large-scale analyses have illuminated long-term comparative wear rates and their dependence on design and patient factors. Our study of a large retrieval archive of knee inserts indicates that abrasive/adhesive wear of polyethylene inserts, both on the articular surface and on the backside of modular knees is an important contributor to wear, generation of debris and integrity of locking geometry.

The objective of the current study is to quantify wear performance of tibial inserts in a large archive of retrieved knees of different designs. By assessing wear in a large and diverse series, the goal is to discern the effect on wear performance of a number of different factors: patient factors that might help guide treatment, knee design factors and bearing material factors that may inform a surgeon's choice from among the array of arthroplasty device options.

Methods

An IRB approved retrieval database was queried for TKA designs implanted between 1997 and 2017. 1385 devices from 5 TKA designs were evaluated. Damage was ranked according to Hood's method, oxidation was determined through FTIR, and wear was determined through direct measurement of retrieved inserts using a previously established protocol. Design features (e.g. materials, conformity, locking mechanisms, stabilization, etc.) and patient demographics (e.g. age, weight, BMI, qualitative activity level, etc.) were cataloged. Multivariate analysis was performed to isolate factors contributing to wear, oxidation, and damage.

Results

Wear and oxidation were both found to scale with time in vivo in conventional and crosslinked polyethylene. Wear rate was also found to scale with time in vivo, but was not found to be a function of oxidation. Regression shows patient age and female sex to correlate negatively with wear rate. Polished trays, crosslinked polyethylene, and constrained knee designs are all correlated with decreased wear rates.

Discussion

While this study indicates that loosening and infection are predominant causes for TKA revision, wear related failure remains common. We believe this to be the largest existing comparative study of modern TKA wear rates. Insert wear is shown to correlate with several patient factors. Wear performance also varies significantly between knee designs, polyethylene material choice and tray surface finish. When compared to a historical standard for knee wear rates, all designs evaluated in the current study exhibited significant improvements in wear rates. Retrieval analysis can provide insight into implant and patient related factors that contribute to knee wear, with the goal of improving patient outcomes and best matching design decisions to patient populations.

Figures

Design Series	N	Average months in vivo	Average Patient Age at Implant (years)	Average BMI
A	488	70.9	61.5	32.7
B	403	43.9	59.4	34.5
C	255	58.1	59.6	34.2
D	143	33.8	62.1	32.8
E	96	49.7	59.3	32.9
Total	**1385**	**55.0**	**60.4**	**33.5**

Figure 1. Retrieved devices can be grouped into 5 major designs

Figure 1

Category	Reason for Revision	# of Cases	Top 6 RFR	Duration Mean (Median)
Wear	Poly Wear	101	8%	98.2 (99.4)
	Failed Poly	7		
	Osteolysis	61	5%	
Loose/ Subsidence	Loose	381	30%	64.1 (52.5)
	Subsidence	15		
Mechanical	Instability	176	14%	42.3 (32.6)
	Malposition	41		
	Dislocation	14		
	Subluxation	2		
	Poly Disassociation	2		
Soft Tissue	Pain	91	7%	39.4 (23.7)
	Stiffness	6		
	Range of Motion	4		
	Infection	334	26%	
	Arthrofibrosis	21		
	Bleeding	18		
	Size	11		
	Amputation	1		
TOTAL		1286	89%	

Figure 2. Surgeon reported reasons for retrieval grouped by major category, including the top 6 reasons and in vivo duration. 99 Devices excluded due to implant fracture, metal reaction, or unreported reason for revision

Figure 2

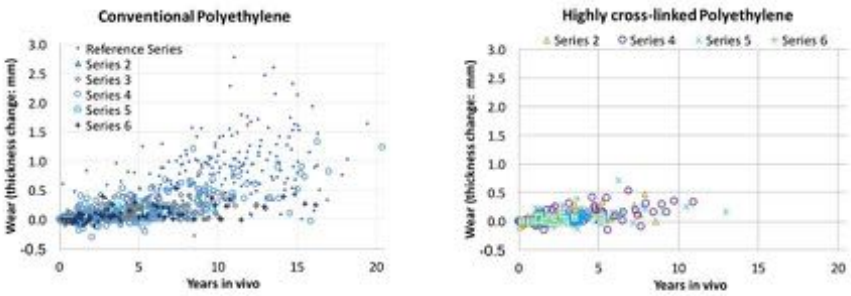

Figure 3. Wear for all devices increases with time in vivo for conventional and highly crosslinked bearings

Figure 3

Wear, Not Corrosion, Is a Feature of the Axles in Retrieved Distal Femoral Replacements

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Background:

Distal femoral replacements (DFR) are used in children for limb-salvage procedures after bone tumor surgery. These are typically modular devices involving a hinged knee axle that has peripheral metal-on-polyethylene (MoP) and central metal-on-metal (M-M) articulations (Fig 1). While modular connections and M-M surfaces in hip devices have been extensively studied, little is known about long-term wear or corrosion mechanisms of DFRs. Retrieved axles were examined to identify common features and patterns of surface damage, wear and corrosion.

Methods

The cobalt chromium alloy axle components from 13 retrieved DFRs were cleaned and examined by eye and with a stereo microscope up to 1000x magnification. Each axle was marked into 6 zones for visual inspection: the proximal and distal views, and the middle (M-M) and 2 peripheral (MoP) zones (Fig 1A). The approximate percentage of the following features were recorded per zone: polishing, abrasion or scratching, gouges or detectable wear, impingement wear (i.e. from non-intentional articulation), discoloration and pitting.

Results

In each case, the middle M-M zones showed more damage features compared with peripheral MoP zones. Brown discoloration, presumably due to tribofilm deposits, was the predominant M-M area feature, particularly at the junction between the MoP and M-M zones (Fig 2A). Higher magnification showed areas of polishing underlying the discoloration, suggesting repetitive removal of the surface metal and re-deposition of tribofilms (Fig 2B). 9 cases demonstrated reflective patches resembling “thumbprint” or “fish scale” markings, which, under higher magnification, showed signs of scratching and grooving in a radial pattern (Figs 2D, 3A). Pits were occasionally present but appeared to be from third-body damage as signs of corrosion were absent (Fig 2E).

Features that resembled carbides, sometimes with associated “comet” patterns of scratching were apparent under higher magnification in some areas (Fig 3B).

The MoP zones showed variable scratching, abrasion and wear polishing (Fig 2C). The MoP to M-M junctional areas were demarcated by a distinct band corresponding in some cases to a narrow wear groove or gouge (Fig 2F). 3 axles had evidence of severe impingement wear on one proximal end (Fig 3C).

Discussion

This study of retrieved axle components demonstrated varying types of surface wear damage but no clear evidence of corrosion. Third-body damage may have resulted from the breakdown of surface carbides, leading to scratching, abrasion and wear polishing under high contact stress. Severe impingement wear presumably occurred after catastrophic damage to the polyethylene bushings, allowing eccentric loading and extensive metal wear. The components were revised for a range of clinical reasons including aseptic loosening and the need to expand the prosthesis during growth. With the exception of the few cases with severe impingement, it is unlikely that the wear features seen here contributed to the need for revision. While it was reassuring that corrosion was not a feature of these M-M articulations, retrieval analysis of DFR components should be continued to confirm this finding, better document the in vivo wear processes and point to design features that might be improved for future patients.

Figures

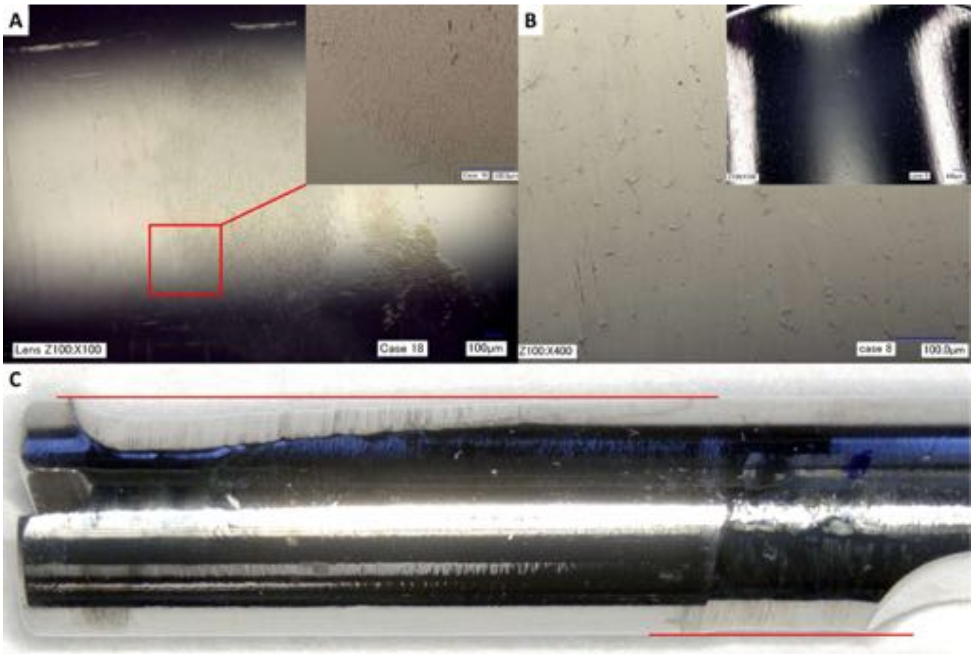

Figure 1

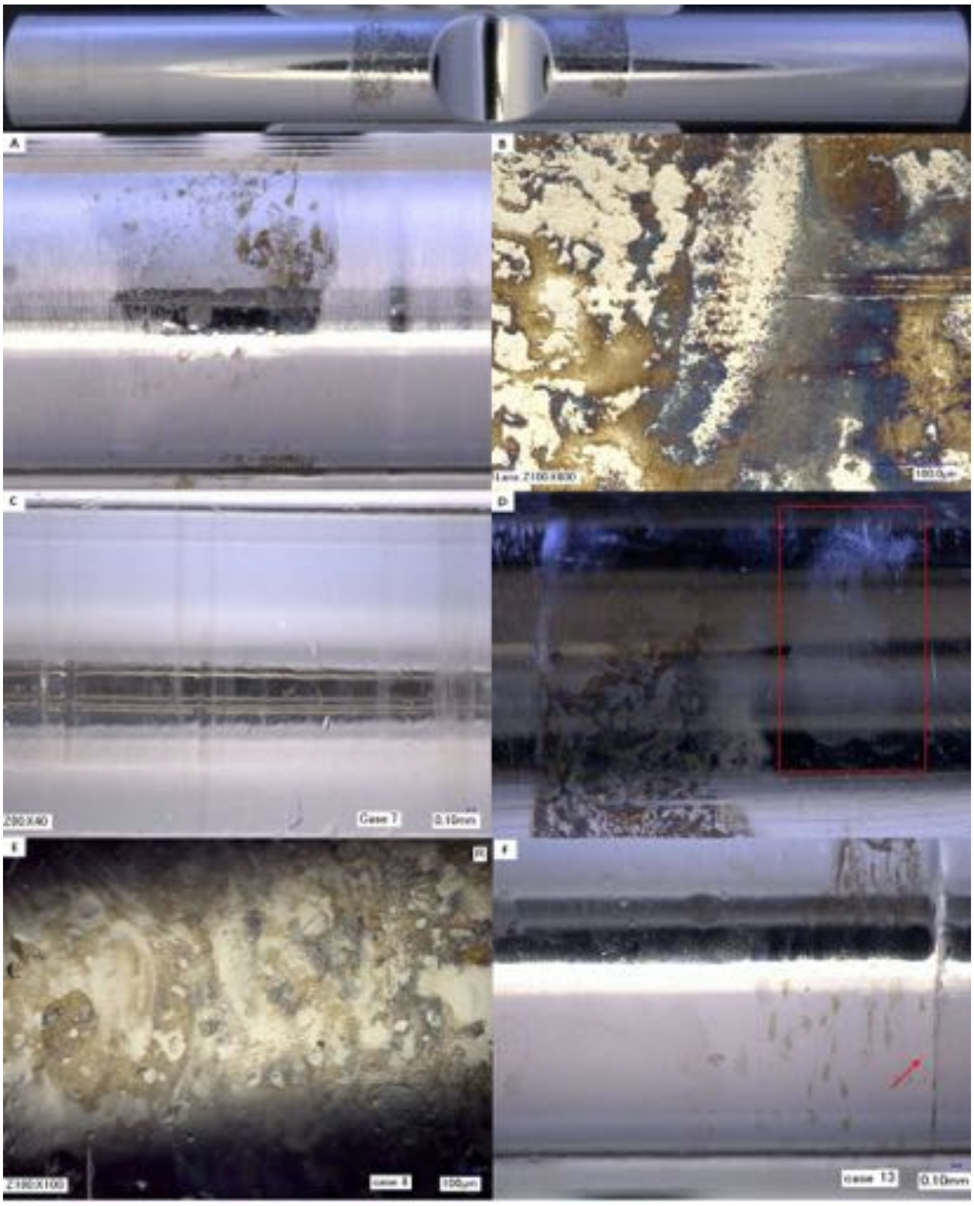

Figure 2

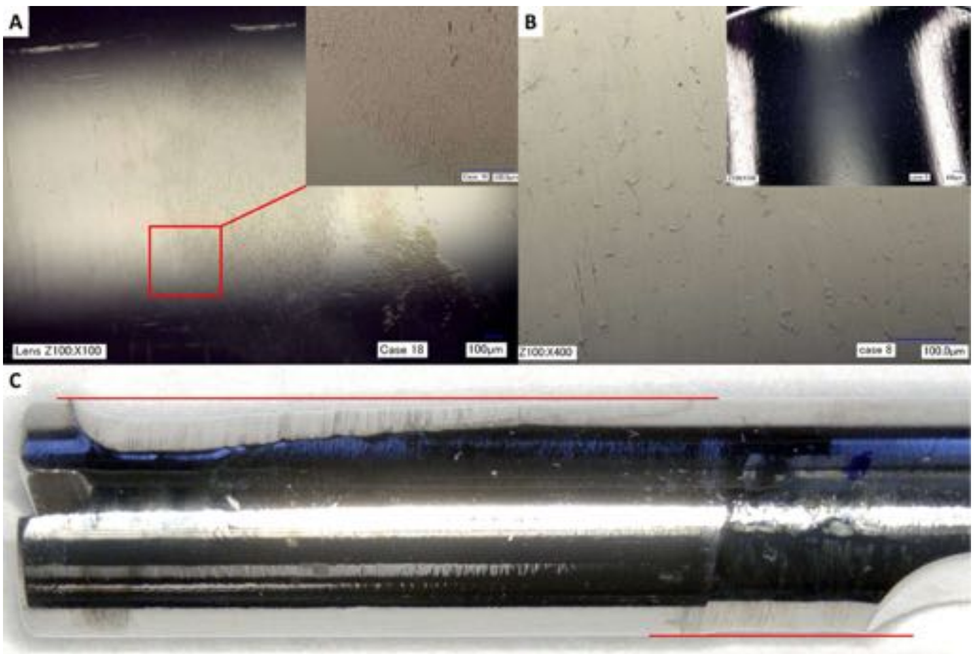

Figure 3

#6070

Gait-Dependent Model of Wear From Retrieved Total Knee Replacement Components

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INTRODUCTION: Studies of retrieved TKR components demonstrate that *in vivo* wear on the articular surface of polyethylene liners exhibits a much higher variability on their *in vitro* counterparts.[1] Only one study has attempted to validate a patient-specific model of wear with a clinically retrieved component.[2] The purpose of this study is to investigate the relationship between observed TKR contact conditions during gait and measured volume loss on retrieved tibial components.

METHODS: Eleven retrieved ultra-high molecular weight polyethylene (UHMWPE) cruciate-retaining tibial liner components from ten separate patients (implantation time = 8.6±5.6 years) had matching gait trials of normal level walking for each knee. Volume loss on retrieved components was calculated using a coordinate measuring machine and autonomous reconstruction.[3] Motion analysis of normal level walking gait had been conducted between 1986 and 2005 for various previous studies and stored in a consented Human Mechanics Repository, ranging from pre-operative to long-term post-operative testing. Contact location between the femoral component and the tibial component on the medial and lateral plateaus were calculated throughout stance.[4] A previously validated and fine-tuned parametric numerical model was used to calculate TKR contact forces for each gait trial.[5] Vertical contact forces and contact paths on the medial and lateral plateaus were input as normal force and sliding distance to a simplified Archard equation for wear with material wear constant = 2.42×10^{-7} mm^3/Nm[2,6] to compute average wear per gait cycle. Wear rates were calculated using linear regression, and Pearson correlation examined correlations between modeled and measured wear.

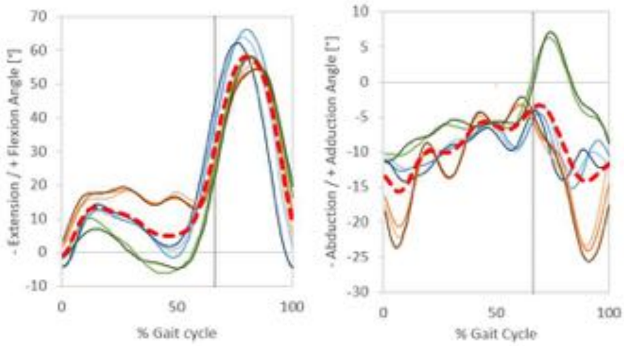
RESULTS: Secondary motions at the knee from gait testing showed distinct grouping between trials of each patient (Fig. 1). Three components demonstrated severe polyethylene delamination and were excluded from wear rate analyses. All calculated wear rates for measured and modeled volume loss, shown in Fig. 2, showed excellent agreement and were not significantly different (Table 1). Volumes were significantly correlated between measured and modeled wear for the total part and on the medial side, but not for the lateral side (Table 1).

DISCUSSION: Measured wear rates were comparable to a previous study of a large population of retrieved MGII components.[7] As seen in Fig 2b, medial wear volumes for six of eight mild wearing components were closely tracked by their modeled counterparts. Because the Archard equation produces wear volumes that are linearly related to time *in situ*, deviations from linear predictions arise from patient-specific variations in contact forces and tibiofemoral pathways during normal walking gait. As suggested by the results of the current study, these variations in gait between patients result in meaningful differences to the wear of the UHMWPE component. Despite many assumptions, this study demonstrates the feasibility of a patient-specific model of wear using a rare population of gait-matched retrievals.

REFERENCES: [1] Harman 2009, JOR 27, 540–548. [2] Fregly 2005, JBiomech 38, 305–314. [3] Knowlton 2013, JBMRB 101B, 449–457. [4] Lundberg 2014, Iowa Orthop. J. 34, 94–10. [5] Lundberg 2013, J. Biomech. Eng. 135, 0210151–0210159. [6] Knight 2007, JBiomech 40, 1550–8. [7] Pourzal 2016, CORR 474(8):1867-75.

Figures

Figure 1: Kinematic motions of the knee for eight trials of three patients (blue, orange and green lines) during gait. Multiple trials of each patient show distinct grouping. Mean kinematics motions (red dashed line) were applied to the all other gait trials in which no secondary kinematics were available. The average end of stance (toe-off) is marked by the black dashed line.



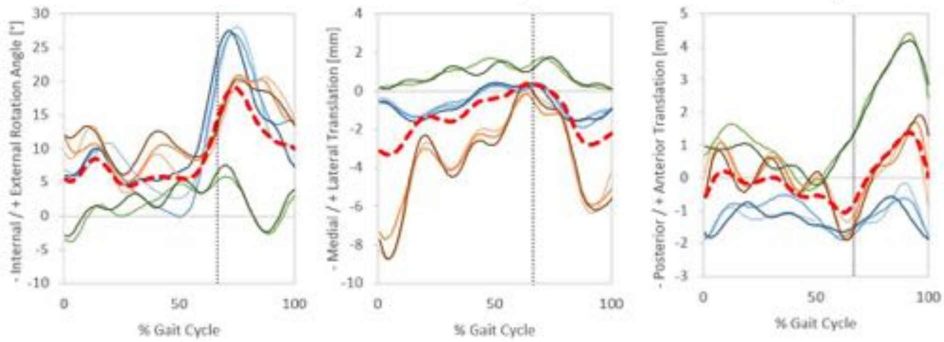


Figure 1

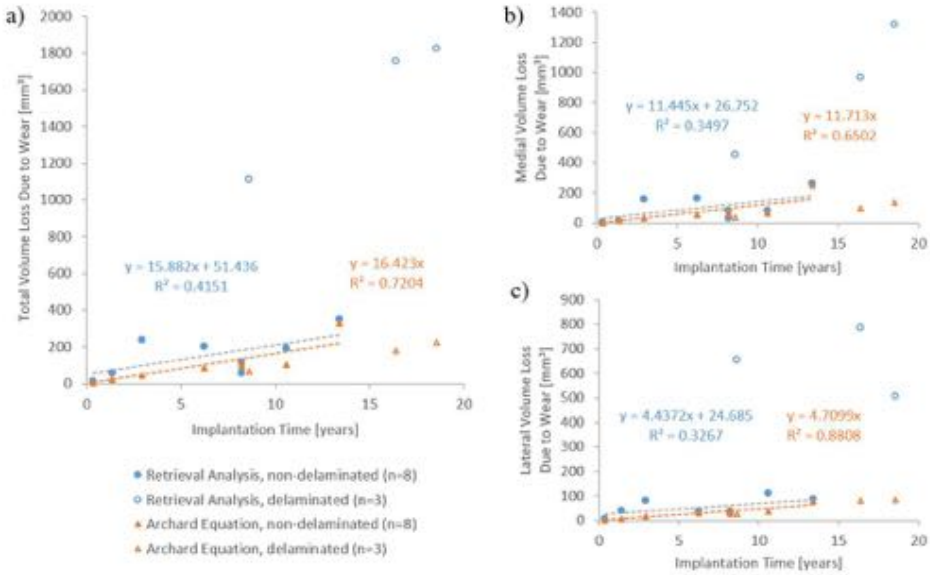


Figure 2: Measured (blue ●) and modeled (orange ▲) volume loss due to wear against implantation time for the (a) total part, (b) medial plateau and (c) lateral plateau. Three parts that exhibited severe delamination were excluded from wear rate calculations for both measured (○) and modeled (△) volume loss.

Figure 2

Table 1: Wear rates from measured volume loss after adjusting for creep and predicted volume loss due to wear from the Archard equation, represented by the slope of the regression line ± standard error (with significance values for regressions). Student t-tests were performed between measured and modeled wear rates, as well as Pearson correlations and significance values between measured and modeled volume loss.

	Total Wear Rate [mm^3/year]	Medial Wear Rate [mm^3/year]	Lateral Wear Rate [mm^3/year]
Retrieval Analysis (n=8)	15.9 ± 7.7 (p=0.057)	11.4 ± 6.4 (p=0.084)	4.4 ± 2.6 (p=0.096)
Archard Equation (n=8)	16.4 ± 2.4 (p=0.002)	11.7 ± 2.1 (p=0.006)	4.7 ± 0.4 (p<0.001)
Student t-test between wear rates	p=0.956	p=0.974	p=0.926
Pearson correlation between modeled and measured wear volumes	0.758 **(p=0.017)**	0.780 **(p=0.012)**	0.482 (p=0.154)

Figure 3

#5925

In-Vivo Performance of Surface-Hardened Ti-Alloy Knee Prostheses

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Introduction: The association between CoCr joint replacements and adverse tissue reactions has led to increased interest in alternative materials that are both biocompatible and wear-resistant. Although the most direct solution would appear to be to completely eliminate Co and Cr, other biocompatible alloys, especially those based on Ti, Ta and Zr have inadequate abrasion and wear resistance for use as bearing materials in the body. This has led to alternative solutions, including surface hardening of titanium alloys to increase their resistance to third-body abrasion. In this study, we review the performance of nitrogen-hardened TiAlV femoral components retrieved after periods of up to 20 years in situ, in comparison with CoCr components of similar design.

Methods: Nitrogen surface-hardened TiAlV femoral knee implants (MGII TiNidium, Zimmer) were retrieved from 18 patients at revision surgery after 1 to 20 years in vivo (average period of implantation: 7.7±6.8 years). A control group of 18 CoCr components (NexGen, Zimmer) retrieved after a similar duration of implantation (6.7±5.6 years) were characterized for comparison. The bearing surface of each component was inspected by stereomicroscopy (x6-x32), and graded for pitting, abrasion, scratching, and burnishing. A variation of the Injury Severity Score system (ISS) was used to calculate a composite damage score based on the area of involvement (0-10%=1, 10-50%=2, over 50%=3) of 6 zones located over the articulating surfaces of each implant. Based on the ISS score, the femoral components were classified as having slight, average, or severe surface damage. Representative specimens from each of these groups were subjected to SEM imaging, optical profilometry (n=12), and incremental nano-indentation hardness tests (n=3; Hysitron TI 950 TriboIndenter).

Results: There was no difference between the severity of surface damage of the nitrogen-hardened TiAlV femoral components and the CoCr controls (Damage scores: TiNidium : 40±5 points vs CoCr: 39±5 pts.; p=0.67; Table 1). The rate of surface damage was greatest in the first 2 years then decreased exponentially (Figure 1). Surface roughness (Ra) values were similar for both groups (TiAlV: 0.771um; CoCr: 0.884um) but decreased with the severity of visual damage in the TiNidium implants due to secondary burnishing of scratches. As seen in the nano-hardness profile of Figure 2, the hardness of the TiNidium components exceeded 7GPa to a depth of approximately 140nm from the surface and decreased monotonically from 140-200nm as the substrate was approached. In contrast, the hardness of the CoCr controls remained reasonably consistent (7.3 ±0.07GPa), independent of depth from the surface. For reference purposes, the nano-hardness of conventional TiAlV alloy is reported to be 4.7 to 5.3 GPa.

Conclusions: Our findings show that:

1. The CoCr and surface hardened TiAlV femoral (TKR) components examined in this study exhibited a similar level of resistance to surface damage in vivo.
2. Most of the damage occurs within the first 1-2 years of the service life of the implants.
3. In the absence of definitive wear testing, multiple complementary methods of are needed to evaluate the performance of surface hardened implants using components retrieved at revision.

Figures

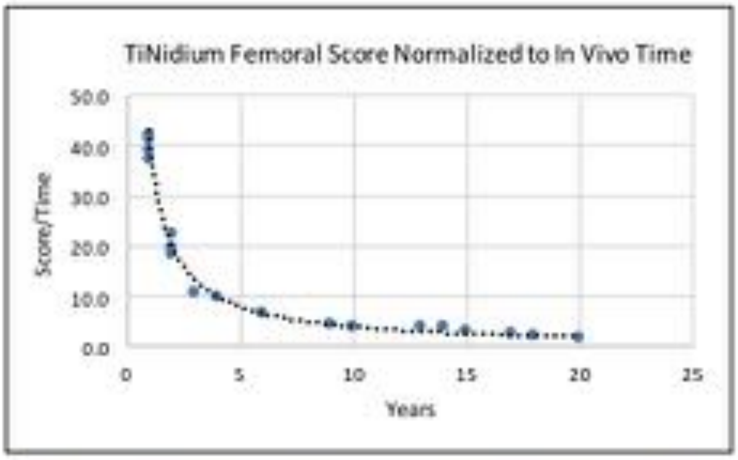

Figure 1. Variation in the rate of surface damage with the duration of implantation (TiNidium components)

Figure 1

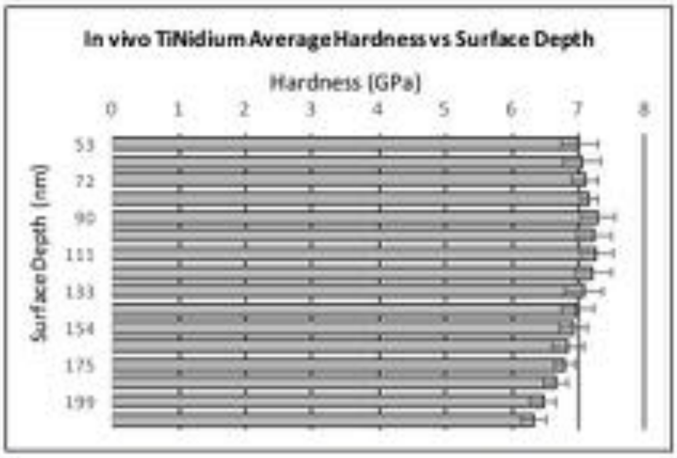

Figure 2. Variation of the surface hardness of the retrieved TiNidium implants as a function of depth below the articulating surface (53-199nm).

Figure 2

Table 1. Summed damage scores for articular zones of the femoral components

Material	Pitting / Etching	Abrasion	Scratching	Burnishing	Total	Std Dev
TiNidium	8	7	11	14	40	5
CoCr	8	9	11	13	39	5

Figure 3

In Vitro Wear at the Taper-Trunnion Junction of BIOLOXdelta Hips Shown in a Multi-Station Hip Simulator

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Introduction

The bearing surfaces of ceramic-on-ceramic (CoC) total hip replacements (THR) show a substantially lower wear rate than metal-on-polyethylene (MoP) THR *in-vitro*. However, revision rates for CoC THR are comparable with MoP. Our hypothesis that an explanation could be adverse reaction to metal debris (ARMD) from the trunnion led us to investigate the wear at both the bearing surfaces and the taper-trunnion interface of a contemporary CoC THR in an *in-vitro* study. Additionally, a dynamically loaded 'control' sample was employed to investigate whether measurements from it would influence the gravimetrically calculated wear of the CoC hip joints.

Methods

Three 36mm CoC hips were tested in a hip simulator for 5 million cycles (Mc), with a fourth sample serving as a dynamically loaded control. BIOLOX®delta ceramic femoral heads were mounted on 12/14 titanium (Ti6Al4V) trunnions. Wear of femoral heads, acetabular liners and trunnions was determined gravimetrically in two ways: a. uncorrected (without considering the control) b. corrected (with the control). Roughness measurements (Sa) were taken on the articulating surfaces (pre and post-test) and on the trunnion surfaces (worn and unworn). Furthermore, Energy Dispersive X-ray Spectroscopy (EDX) was used to identify and quantify the wear debris present in the lubricant using scanning electron microscope (SEM).

Results and Discussion

The total uncorrected volumetric wear was 0.25 mm^3 for CoC joints and 0.29 mm^3 for titanium trunnions see Figure 1.a. The total corrected volumetric wear was 0.02 mm^3 for CoC joints and 0.23 mm^3 for titanium trunnions see Figure 1.b. Both uncorrected and corrected total wear volumes of the titanium trunnions are in agreement with an explant study[1] which quantified the volumetric material loss from retrieved trunnions with the total wear ranging from 0.0-0.74 mm^3. Pre-and post-test measurements for Sa of heads and liners did not show a statistically significant change, see Figure 2. The Sa of the trunnions on the unworn and worn areas showed a statistically significant decrease from 0.558 ± 0.060 to 0.312 ± 0.028 µm respectively ($p < 0.001$), see Figure 3. Analysis of wear debris within the lubricant confirmed the presence of titanium. A recent clinical study[2] found more ARMD in CoC hips than MoP hips. This is despite there being fewer metallic components in a CoC hip than a MoP hip. This *in vitro* study has shown that one source of metal debris in a CoC hip is the taper-trunnion junction.

Conclusion

An explanation for wear related failures in ceramic-on-ceramic hip arthroplasty, despite the low wear arising at the articulating surfaces, may now exist; namely that titanium wear particles are generated from the trunnion. No other long-term hip simulator studies have measured wear at the taper-trunnion junction. Furthermore, as a loaded control specimen was shown to have a significant effect when wear testing CoC hips, we suggest that ISO14242[3] be amended so that control samples are included.

Acknowledgements

Thanks to Mark Minta (University of Surrey) for wear debris analysis.

References

1. Kocagoz *et al,* 2016, CORR.
2. Matharu *et al,* 2016, BMC Musc Dis.
3. ISO 14242-1, 2014.

<u>Figures</u>

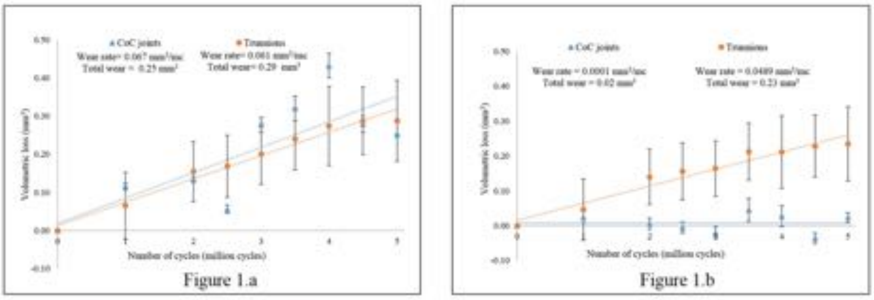

Figure 1 Mean volumetric measurements of CoC joints and trunnions a. uncorrected and b. corrected (Error bars represent standard deviation)

[Figure 1](#)

Mean Sa (in µm)	0 mc (Mean ± SD)	After 5 mc (Mean ± SD)	p-value
Femoral heads	0.003 ± 0.002	0.004 ± 0.001	p= 0.184
Acetabular liners	0.005 ± 0.001	0.005 ± 0.001	p= 0.184

Figure 2 Table of pre and post-test mean surface roughness (Sa) measurements of femoral heads and acetabular liners

[Figure 2](#)

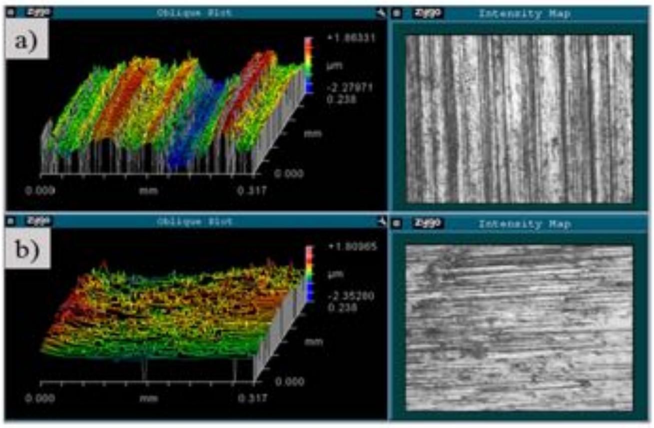

Figure 3 Surface topography images of a titanium trunnion a) unworn with machining marks visible (Sa = 0.565 µm) and b) worn (Sa = 0.284 µm).

Figure 3

Development of a Pre-Clinical Test to Evaluate Total Shoulder Arthoplasty

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Introduction

Shoulder arthoplasty has increased in the last years and its main goal is to relieve pain and restore function. Shoulder prosthesis enters in the market without any type of pre-clinical tests. Within this paper we present study experimental and computational tests as pre-clinical testing to evaluate total shoulder arthoplasty performance.

Materials and methods

An in vitro experimental simulator was designed to characterize experimentally the intact and implanted shoulder glenoid articulation. Fourth generation Sawbones® composite left humerus and scapula were used and the cartilage was replicated with silicone for the intact articulation (figure 1). In the intact experimental articulation we considered the inferior glenohumeral ligament as an elastic band with equivalent mechanical properties. For the implanted shoulder, the Comprehensive® Total Shoulder System (Biomet®) with a modular Hybrid® glenoid base and Regenerex® central post was considered (figure 2). The prostheses were implanted by an experienced surgeon and clinical results from orthopedic registers were collected.

The system structures were placed to simulate 90º in abduction, including the following muscle forces: Deltoideus 300N, Infraspinatus 120N, Supraspinatus 90N and Subscapularis 225N. The finite element model was created with tetrahedral linear elements with linear elastic and isotropic material for the humerus in figure 3, (Young's modulus for cortical bone - 16.5 GPa; trabecular bone - 124 MPa). Anisotropic behavior was considered for the scapula model ($E11$ = 342.1 MPa, $E22$ = 212.8 MPa, $E33$ = 194.4 MPa). The shoulder prosthesis was of polyethylene with 1GPa and titanium with 110 GPa. The Poisson's ratio was 0.3 in all material, except for polyethylene where we assumed a value of 0.4. A long-term post-operative condition was simulated.

Results

The experimental results were compared with numerical ones for model validation. The strains measured evidence the effect of the implant presence, manly in the scapula. In the anterior region presents an increase of strains (+26%) was observed for the anterior region and decrease (-52%) in the posterior region, suggesting strain shielding in figure 4.

At the glenoid cavity, the numerical principal strains present safety values of strains (200 to 2500) με in both axial and coronal planes. This indicates that on the long-term the glenoid prosthesis is well fixed to the surrounding bone tissue and bone integrity is maintained despite the presence of the implant. However there are some peak values (2500, 25 000 με) that were observed in some small areas in the posterior and distal regions. Results were compared with clinical ones.

Discussion and Conclusions

The proposed pre-clinical test with the articulation at 90º in abduction can predict bone behavior when total shoulder prosthesis is implanted and in the long term post-operative condition. The results obtained evidence some critical regions around the glenoid component. This pre-clinical test can be implemented to improve the concepts before market.

Figures

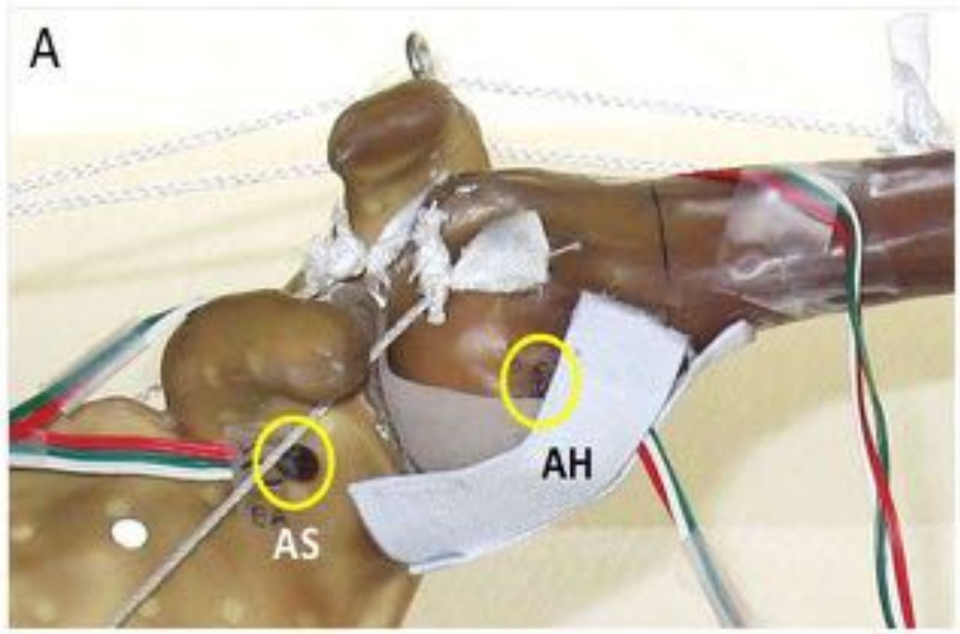

Figure 1 – In vitro intact shoulder articulation

Figure 1

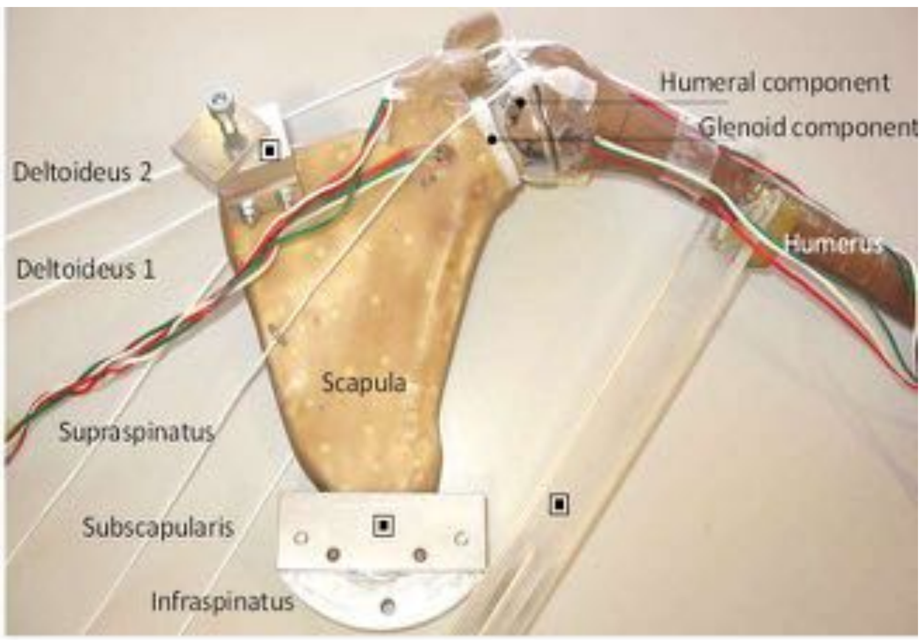

Figure 2 – In vitro implanted total shoulder articulation

Figure 2

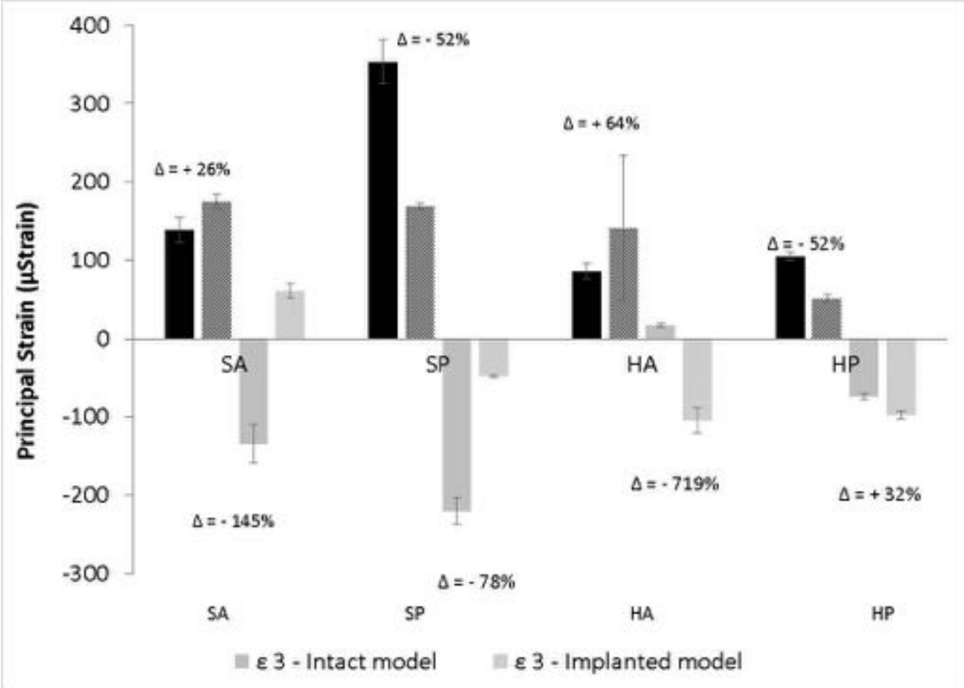

Figure 4 – Experimental and numeric comparison in the strain gauges location

Figure 3

#6063

Novel 3D-Printed Patient-Specific Guide Improves Glenoid Pin Placement Compared to Standard TSA Guide: A Cadaveric Study

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Background: Accurate placement of the glenoid component in total shoulder arthroplasty (TSA) is critical to optimize implant longevity. Commercially available patient-specific instrumentation systems can improve implant placement, but may involve considerable expense and production delays of up to six weeks. The purpose of this study was to develop a novel technique for in-house production of 3D-printed, patient-specific glenoid guides, and compare the accuracy of glenoid guidepin placement between the patient-specific guide and a standard guide using a cadaveric model.

Methods: Twenty cadaveric shoulder specimens were randomized to receive glenoid guidepin placement via standard TSA guide (Wright Medical, Memphis, TN) or patient-specific guide. Three-dimensional scapular models were reconstructed from CT scans with Mimics 20.0 imaging software (Materialise NV, Leuven, Belgium). A pre-surgical plan was created for all specimens for the central glenoid guidepin of 0º version and inclination angles. Central pin entry and exit points were also calculated. Patient-specific guides were constructed to achieve the planned pin trajectory in Rhino3D software (Robert McNeel & Associates, Seattle, WA). Guides were 3D-printed on a Form2 printer with Formlabs Dental SG Resin (Formlabs, Somerville, MA). Glenoid labrum and cartilage were removed with preservation of other soft tissues in all specimens to mimic intraoperative TSA conditions. A fellowship-trained, board-eligible orthopaedic surgeon placed a 2.5 mm diameter titanium guidepin into each glenoid using the assigned guide for each specimen. After pin placement, repeat CT scans were performed, and a blinded measurer used superimposed 3D scapular reconstructions to calculate deviation from the pre-surgical plan in version and inclination angles, dot product angle, and guide pin entry and exit points (Figures 1 and 2). Student's t tests were performed to detect differences between pin placements for the two groups.

Results: Cadaver age, sex, and BMI did not differ between groups ($p>0.05$ for all). Average production cost and time for the patient-specific guides were $6.25 and 1.5 days per guide, respectively. Guidepin version deviation did not differ between the patient-specific and standard guides (1.59º ± 1.60º versus 2.88 º ± 2.11º, respectively, $p=0.141$). Guidepin inclination deviation was significantly lower in the patient-specific group (1.54º ± 1.58º versus 6.42º ± 5.03º, $p=0.009$), similarly the dot product angle was lower in the patient-specific compared to standard guide group (2.35º ± 1.66º versus 7.48º ± 4.76º, $p=0.005$). Glenoid entry site exhibited less deviation for the patient-specific compared to standard guide (0.75mm ± 0.54mm versus 2.05mm ± 1.19mm, $p=0.006$). Glenoid exit site also was closer to the target for the patient-specific compared to standard group (1.75mm ± 0.99mm versus 4.75mm ± 2.97mm, $p=0.010$).

Conclusion: We present a novel technique for in-house production of 3D-printed, patient-specific glenoid guides for TSA glenoid pin placement. These patient-specific guides improved pin placement accuracy based on 3D-CT measurements compared to standard TSA guides in a cadaveric model. Our patient-specific glenoid guides can be

produced on-demand, in-house, inexpensively, and with significantly reduced time compared to commercially available guides. Future studies are required to validate these findings in clinical applications and determine the potential impact on implant longevity.

Figures

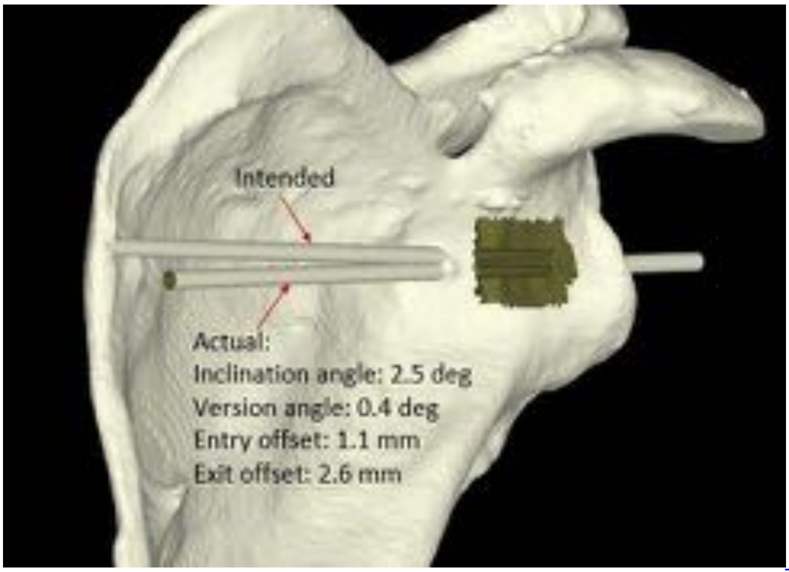

Figure 1

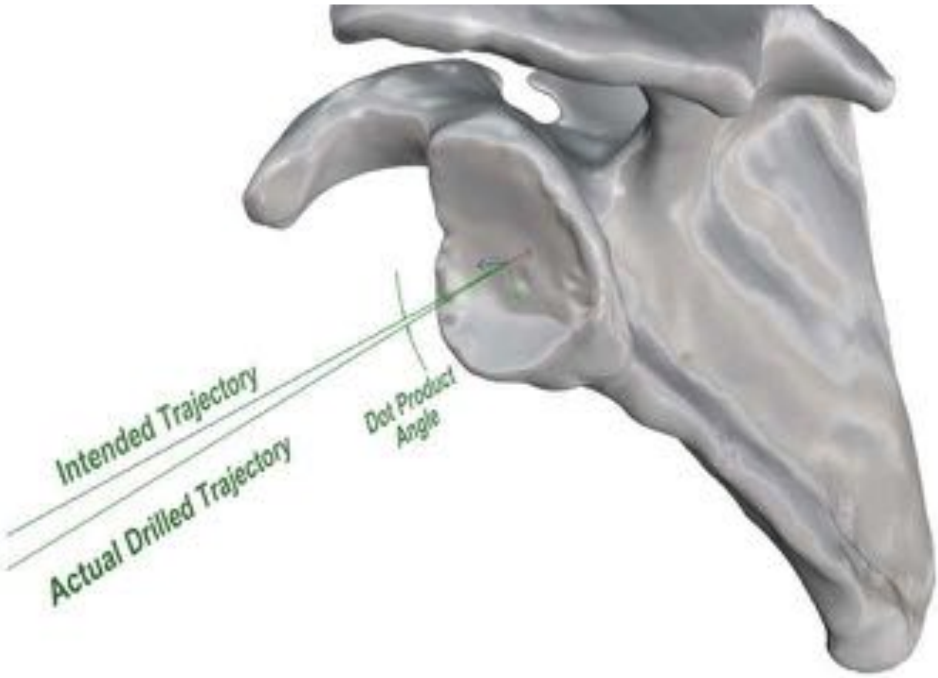

Figure 2

#6089

Laboratory and Clinical Study for Using PSI in Positioning Gelnoid Components

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Background: longevity and survivorship of the total anatomic shoulder arthroptasty in osteoarthritic patients depends on both accurate correction of glenoid deformity and correct position of the endoprosthetic components. On the contrary, component malposition is highly associated with poor function and early failure. The purpose of this study is to assess the accuracy of computer-assisted 3-Dimensional preoperative planning and patient-specific instrumentation in shoulder arthroplasty. Methods: A pilot cadaveric and then clinical intervention study were constructed into 2 phases. Phase I was done on 5 pairs of dry bone cadavers (5 scapulae and their corresponding humerus bones): preoperative computerized tomography examinations were performed, followed by computer-assisted-preoperative planning and then patient-specific guides created to direct the guide pin into the desired pre-allocated position (Figure 1). A postoperative computed tomography scan was done after the procedure. The differences in desired and achieved results were analyzed (Figure 2). Phase II had a clinical trial on 3 patients for clinical application to test the practicality and accuracy of such technology in achieving satisfactory alignment in shoulder replacement surgeries. Results: computer-assisted 3-Dimensional planning and patient-specific instrumentation was feasible and accurate in proper prosthetic implants' components in shoulder replacement. Conclusion: Recent advances in 3-dimensional imaging techniques, preoperatrive computer-assisted planning and patient-specific instrumentations may potentially address some of the common difficulties encountered by surgeons.

Figures

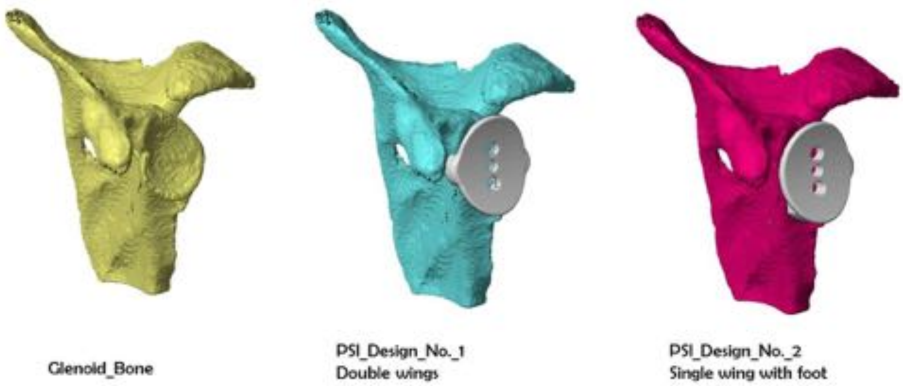

Figure 1

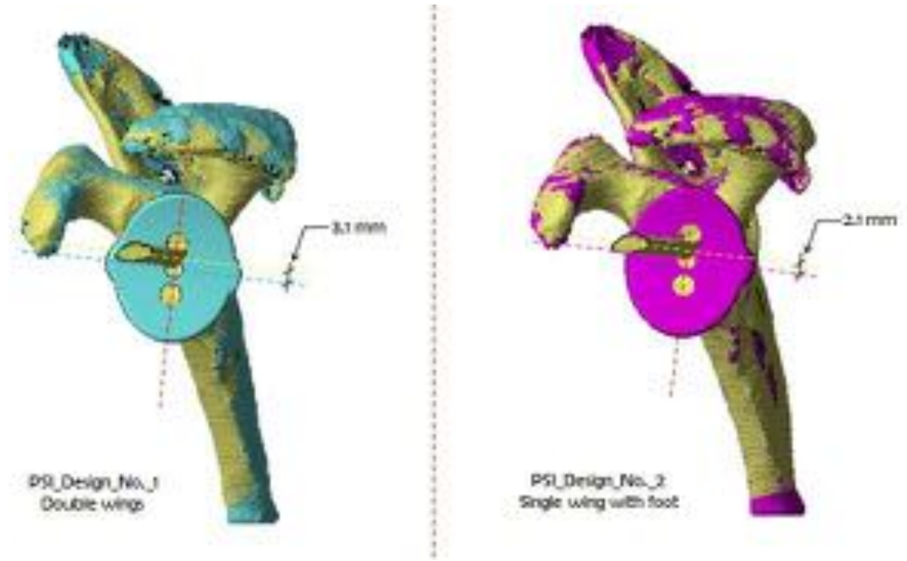
3.1 mm
2.1 mm
PSI_Design_No._1
Double wings
PSI_Design_No._2
Single wing with foot

Figure 2

#5725

Influence of Humeral Stemless Implant Geometries on Primary Stability Under Physiological Loading

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Introduction

The long term success of uncemented humeral stemless implants relies on adequate primary stability, which can, among other parameters, be influenced by implant design.

The objective was to compare the primary stability of two different humeral stemless implant geometries, in the anatomical configuration, in response to loading conditions representative of upper limb daily life activities, and assess if a design may be better suited for a given set of activities.

Methods

This finite element study was based on an established method [1]. Two commercially available stemless implants (subject to regulatory clearance per region) were virtually implanted in a foam bone block. One implant anchor consists of 4 open and thin wings with a superior collar while the other exhibits 6, thicker wings (Figure 1). In order to isolate the effect of geometry, all parameters but the geometry were kept the same for the two designs. Generic linear-elastic material properties were applied to the cancellous bone (E = 213MPa) and to the titanium implant anchors (E = 114 GPa). A 0.6 friction coefficient was selected for the bone/implant interface [2]. Physiologic glenohumeral joint resultant forces and moments representative of 29 different upper limb activities measured with instrumented shoulder implants [3] were applied to the anchor directly (humeral head not modelled). Micromotion for each design during each activity was assessed, and a linear regression analysis was performed to identify the loading components most affecting micromotion.

Results

Both designs behave in the same manner with respect to the different activities. Both designs were most sensitive to the anterior-posterior shear force component (Figure 2) and to the axial rotation moment component (along the humeral axis). The same 7 activities (combing, lifting 10kg, high and loaded elevation or abduction, painting, hitting a nail) were found in the 10 upper limb activities with the highest AP shear component and in the 10 activities with the highest axial rotation moment arm.

Discussion

Although both implants have very different geometries, the features they do have in common (e.g. the wings perpendicular to the resection plane) may make them respond to the different activities in a similar manner.

The activities that most affected primary stability by inducing a high shear force and a high axial rotation moment involve a loaded hand and/or a hand away from the trunk.

This study focussed on the effect of design alone, neglecting the effect of different surface treatments, press-fit or surgical procedure. These can be accounted for in the next steps to provide input for the next designs and/or guidelines for the rehabilitation period.

References

[1] Favre and Henderson, Clin Biomech 2016

[2] Grant et al., J Biomech 2007

[3] https://orthoload.com/database/ > Shoulder Joint (last visited on Nov 2017)

Figures

The Sidus® Stem-Free Shoulder (left) and Comprehensive® Nano Stemless Shoulder (right), both from Zimmer Biomet

Figure 1

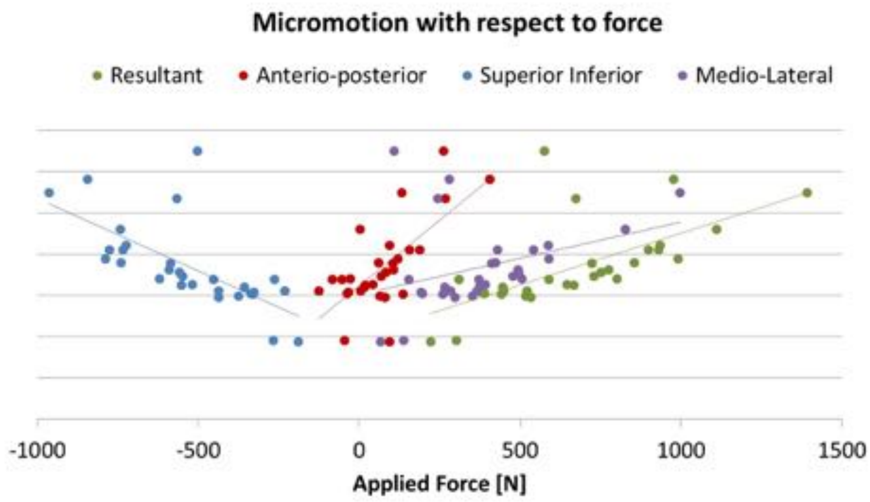

Figure 2: Representative graph showing the sensitivity of peak micromotion to the applied force components.

Figure 2

#5815

Inter-Surgeon Variability in Using 3D Planning Software for Reverse Total Shoulder Arthroplasty: an Analysis of 360 Cases

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Matthew Hamilton - Exactech - Gainesville, USA
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Thomas Wright - UFL - USA
Paul Saadi - Dallas Bone and Joint - Dallas, USA
Joseph Zuckerman - NYU Hospital for Joint Diseases - New York, USA
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INTRODUCTION:

Preoperative planning software for reverse total shoulder arthroplasty (RTSA) allows surgeons to virtually perform a reconstruction based off 3D models generated from CT scans of the glenohumeral joint. While anatomical studies have defined the range of normal values for glenoid version and inclination, there is no clear consensus on glenoid component selection and position for RTSA. The purpose of this study was to examine the distribution of chosen glenoid implant as a function of glenoid wear severity, and to evaluate the inter-surgeon variability of optimal glenoid component placement in RTSA.

METHODS:

CT scans from 45 patients with glenohumeral arthritis were planned by 8 fellowship trained shoulder arthroplasty specialists using a 3D preoperative planning software, planning each case for optimal implant selection and placement. The software provided four glenoid baseplate implant types: a standard non-augmented component, an 8° posterior augment wedged component, a 10° superior augment wedged component, and a combined 8° posterior and 10° superior wedged augment component. The software interface allowed the surgeons to control version, inclination, rotation, depth, anterior-posterior and superior-inferior position of the glenoid components in 1mm and 1° increments, which were recorded and compared for final implant position in each case.

RESULTS:

Two cases were excluded due to extreme deformity and consensus that a feasible RTSA may not be possible. Average version, inclination, and millimeters of bone removed for each case along with standard deviations and implant selection are detailed below in figure 1. For resultant implant version, a bimodal distribution was observed with a local maxima occurring at 0°, and a bell-shaped distribution at -5° of version [Fig 2]. Upon individual surgeon analysis, it was revealed that certain surgeons had a preference to correct to 0 degrees, whereas others were more accepting of residual version. As well, the surgeons accepting residual retroversion removed less bone on average per implant type than the surgeons who aimed to correct to 0°. For resultant implant inclination, surgeons consistently tried to plan for 0 degrees of inclination [Fig 3].

CONCLUSION:

This study indicates that while there was limited consensus on the optimal reconstruction in any one case, there appear to be thresholds of retroversion and inclination that favor the use of augmented glenoid components based on frequency of selection. Our results indicate a wide variability in terms of what experienced shoulder surgeons consider to be an optimal reconstruction despite the common goal of attempting to restore anatomy, maximize implant fixation in bone and minimize bone removal. High frequency of augmented glenoid component use raises questions about how much retroversion and inclination is optimal and whether this technology allows surgeons to potentially focus more on a quantitative reconstruction relative to the Friedman axis versus a qualitative implant placement relative to what may be normal anatomy for a patient.

#6048

Fretting-Induced Metallurgical Transformations in Ti6Al4V Alloy: From Crystalline to Amorphous

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Introduction: Titanium and its alloys are attractive biomaterials because of their desirable corrosion, mechanical, biocompatibility and osseointegration properties. Ti6Al4V alloy in particular remains a prominent biomaterial used in Total Hip Arthroplasty (THA) partly due to CoCrMo alloys being increasingly side-lined for issues with biocompatibility and stress shielding. For several decades now, research efforts have been dedicated to understanding wear, corrosion and surface degradation processes in implant materials. Only recently have researchers shown interest in understanding the subsurface implications of fretting and the role it plays on implant fracture. The purpose of this study is to utilise advanced microscopy and spectroscopy techniques to characterise fretting-induced subsurface transformations in Ti6Al4V. This would enable the possibility of mapping specific regions that are most prone to wear and fatigue failures at the modular taper interface of THA, thus informing better component design and choice of material selection.

Method: A ball-on-flat configuration was utilised in this study to achieve a Hertzian point contact for a CoCrMo – Ti6Al4V material combination. Four fretting displacement amplitudes were assessed: ±10, ±25, ±50 and ±150 µm. An initial contact pressure of 1 GPa was used for all fretting tests in this study and each fretting test lasted 6000 cycles at a frequency of 1 Hz. The simulated physiological solution consisted of Foetal Bovine Serum (FBS) diluted to 25% with Phosphate Buffered Saline (PBS) and 0.03% Sodium Azide (SA) balance. The temperature was kept at ~37°C. Subsurface transformations in the Ti6Al4V alloy was characterised using the Transmission Electron Microscopy (TEM) to obtain high resolution micrographs. The samples were prepared using a FIB-SEM. Bright-field, dark-field and selected area electron diffraction (SAED) patterns were all captured using a scanning TEM (STEM) and Energy Dispersed X-Ray spectroscopy (EDX) mapping was carried out.

Results: At both ±10 and ±25 µm displacement, a stick fretting regime was realised. Subsurface transformation in the Ti6Al4V alloy was characterised as strain-induced orientation. At ±50 µm, a mixed fretting regime was realised, TEM and SAED micrographs as well as EDX spectroscopy identified complex but distinctive structures at the surface and subsurface of the Ti6Al4V alloy. This included a CoCrMo-rich fine particulate, mechanically mixed structure; an amorphous transformed Ti6Al4V structure and a highly nano-crystalline Ti6Al4V structure. At ±150 µm, a full gross slip regime was realised and Ti6Al4V alloy was characterised mainly by subsurface cracks and formation and refinement of nano-crystalline structures.

Conclusion: The degree of subsurface recrystallization was observed to be energy dependent while the manifestation of the energy dissipation was dependent on the contact condition. The interwoven relationship between energy dissipation, contact condition and mechanisms of clinical failure in Ti6Al4V were consolidated in a single map (see Figure 1).

Figures

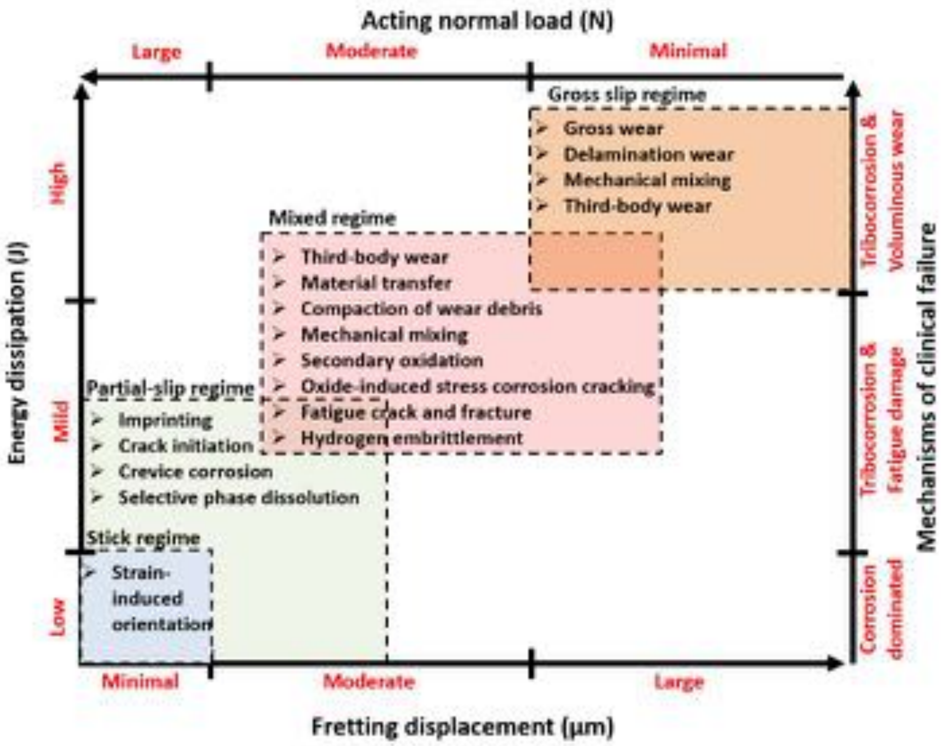
Acting normal load (N)
Large
Moderate
Minimal
Energy dissipation (J)
High
Mild
Low
Gross slip regime
Gross wear
Delamination wear
Mechanical mixing
Third-body wear
Mixed regime
Third-body wear
Material transfer
Compaction of wear debris
Mechanical mixing
Secondary oxidation
Oxide-induced stress corrosion cracking
Fatigue crack and fracture
Hydrogen embrittlement
Partial-slip regime
Imprinting
Crack initiation
Crevice corrosion
Selective phase dissolution
Stick regime
Strain-induced orientation
Minimal
Moderate
Large
Fretting displacement (µm)
Tribocorrosion & Voluminous wear
Tribocorrosion & Fatigue damage
Corrosion dominated
Mechanisms of clinical failure

Figure 1

#5909

A Postmortem Study of Head-Neck Corrosion and Inflammatory Cell Infiltrates in Periprosthetic Tissues and Distant Organs

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INTRODUCTION: Little is known about the relationship between head-neck corrosion and its effect on periprosthetic tissues and distant organs in the majority of patients hosting apparently well-functioning devices. We studied the degree and type of taper damage and the histopathologic response in periprosthetic tissue and distant organs.

METHODS: A total of 50 contemporary THRs (34 primary, 16 revision) retrieved postmortem from 40 patients after 0.4-26 years were studied. Forty-three femoral stems were CoCrMo and 7 were Ti6Al4V. In every case, a CoCrMo-alloy head articulated against a cementless polyethylene cup (19 XLPE and 31 UHMWPE). H&E and IHC sections of the joint pseudocapsules and liver were graded 1-4 for the intensity of various inflammatory cell infiltrates and tissue necrosis. The nature of the tissue response in the joint capsule, liver, spleen, kidneys and lymph nodes was assessed. Wear and corrosion products in the tissues were identified using SEM and EDS. Taper surfaces were graded for corrosion damage using modified Goldberg scoring and examined by SEM to determine the acting corrosion mode. Correlations between damage scores and the histologic variables were generated using the Spearman test.

RESULTS: Perivascular lymphocytes in the pseudocapsules were positively correlated with trunnion damage (r=.458, p=0.001) and head damage scores (r=.322, p=0.022). The distribution of corrosion scores for heads and femoral trunnions is shown in Figure 1. Moderate or severe corrosion of the head and/or trunnion was present in 9 hips (8 CoCr/CoCr and 1 CoCr/TiAlV). One patient with bilateral hips had local ALVAL-like lymphocyte-dominated tissue reactions (Figure 2) and mild focal lymphocytic infiltrates in the liver and kidneys (Figure 3). This was associated with severe intergranular corrosion of the CoCrMo trunnion and column damage on the head taper.

Particle-laden macrophages in pseudocapsules were significantly correlated with liver macrophages (r=.382, p=0.012) and liver lymphocytes (r=.367, p=0.013). Pseudocapsule macrophage responses to metallic and/or polyethylene wear particles ranged widely from minimal to marked. Focal tissue necrosis was related to high concentrations of particulate wear debris. A minimal number of metallic particle-laden macrophages were also detected in the liver and spleen; and macrophage granulomas were present in para-aortic lymph nodes, especially in revision cases.â€‹

DISCUSSION: The generation of metal ions and particulates at corroded CoCrMo heads and CoCrMo or Ti6Al4V trunnions was a significant contributor to the presence of perivascular lymphocytes within the joint pseudocapsule, with 1 patient showing a histologic pattern consistent with ALVAL. Patient factors and the rate of corrosion are among variables influencing whether an ALVAL-type reaction will develop and whether or not it will become symptomatic. Macrophages in the joint pseudocapsules were positively correlated with inflammatory cells in the liver. In this study, the intensity of inflammatory infiltrates in distant organs was mild. However, several cases of organ dysfunction have been reported in association with catastrophic wear of CoCrMo components. It continues to be essential to minimize the generation of metal ions and particulates and to improve strategies for identifying and managing patients exposed to high levels of degradation products.

ACKNOWLEDGEMENT: NIH R01 AR070181

Figures

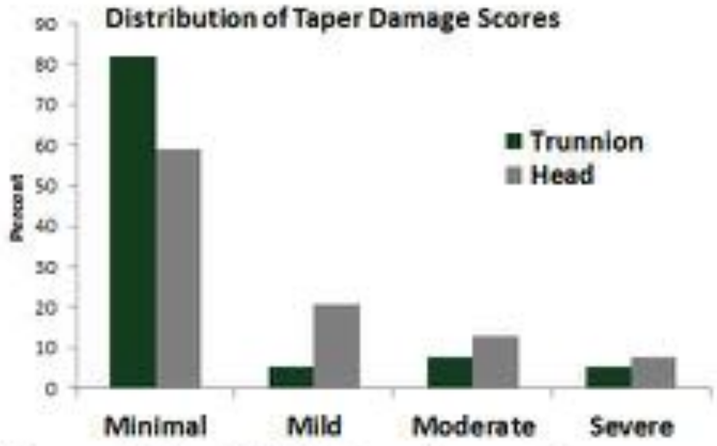

Figure 1. The distribution of corrosion scores for femoral trunnions and heads.

Figure 1

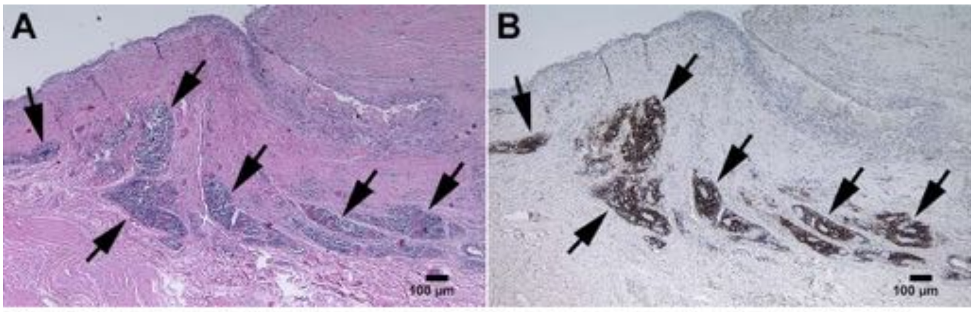

Figure 2. A: Lymphocyte-dominated tissue reaction in the joint capsule from an asymptomatic patient (H&E, 40X). B: Immunohistochemical staining revealed the perivascular lymphocytes to be CD20+ B cells. (40X).

Figure 2

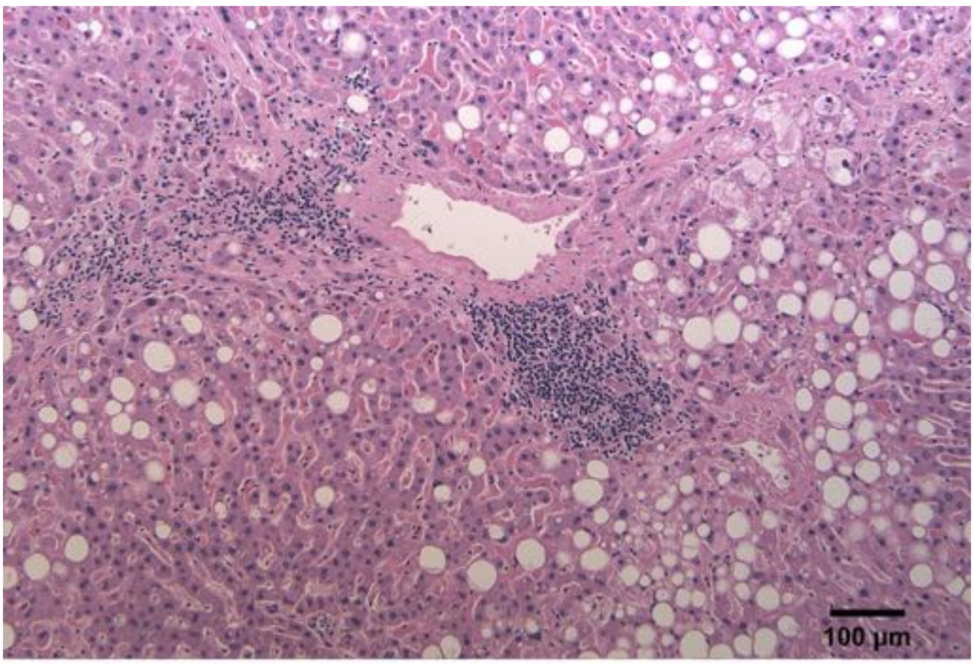

Figure 3. Mild, focal lymphocytic infiltrate in the liver (H&E, 400X).

Figure 3

Mechanisms of Mechano-Tribological Imprinting in in-Vitro Fretting Corrosion of TiAlV/CoCrMo Couples

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Michael Herbig - Max-Planck-Institut fuer Eisenforschung GmbH - Duesseldorf, Germany
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Fretting corrosion of taper junctions is long known and of great concern, because of metal ion and particle release and their related adverse local and systemic effects on the human body[1-3]. Orthopedic taper junctions are often comprised of CoCr29Mo6/TiAl6V4 pairings. Beside others the imprinting of the TiAlV-machining marks into the CoCrMo-taper is of clinical interest [4, 5]. Thus, the multifactorial details and their interdependencies on the macro-, micro, and nanoscale are still a matter of research [6]. This contribution presents the mechanisms of imprinting found in an in-vitro fretting corrosion test. The worn surfaces, the lubricant as well as its remains after test were analyzed and the findings brought into relation to the characteristic wear sub-mechanisms. The fretting tests were conducted by means of a cylinder-on-pin set-up. All details about the test and the sequence of analyses can be found in [7, 8]. A marked tribofilm of C-rich organic matter and oxidized wear particles of both bodies was generated at the TiAlV/CoCrMo contact area (Figure 1a, c). After removing the tribofilm chemically, extremely fine scratches of sub-µm depth became visible on the CoCrMo body (Figure 1b). The TiAlV body showed shallow shelves leaving troughs filled with grainy debris (Figure 1d) mainly of Ti-oxide wear particles. The shelves stick to the surfaces and, therefore, move relatively to the counterbody. In combination with the grainy debris this brings about “Microploughing” on the CoCrMo surfaces. Microploughing is known for destroying any passive film resulting in “Tribocorrosion”. The question remains how the shelves are formed. From the surface analyses one could conclude that they point towards “Delamination”. But this would also mean that they would not stick rigidly to the surfaces but be ejected from the contact area. Focused Ion Beam (FIB) cuts were done in order to investigate the near- and subsurface structure of the shelves in order to clarify the governing mechanisms (Figure 2). Below the platinum protection layer appears a laminated structure of highly deformed nanocrystalline and amorphous areas. EDS confirmed that the lighter intermediate layers consist mainly of Ti-oxide. This microstructure is supposedly formed by severe plastic deformation and the generation of shear bands, which under fretting pile up on top of each other. This cannot be connected to “Delamination”. We therefore propose to categorize the formation mechanism of these shelves as a specific form of microploughing. Thus, imprinting is neither driven by any galvanic effects [9] nor by hardness differences of TiO_2 and Cr_2O_3 [10] but by microploughing on the TiAlV-body leading to tribocorrosion at specific sites of CoCrMo what imprints the surface grooves of the softer TiAlV into the harder CoCrMo.

1 Rostoker et al. (1978)

2 Gilbert et al. (1997)

3 Goldberg et al. (2002)

4	Van Citters et al. (2015)
5	Hall et al (2017)
6	Espallargas et al. (2017)
7	Dufils et al. (2015)
8	Fischer et al. (2017)
9	Langton et al. (2012)
10	Moharrami et al. (2013)

Figures

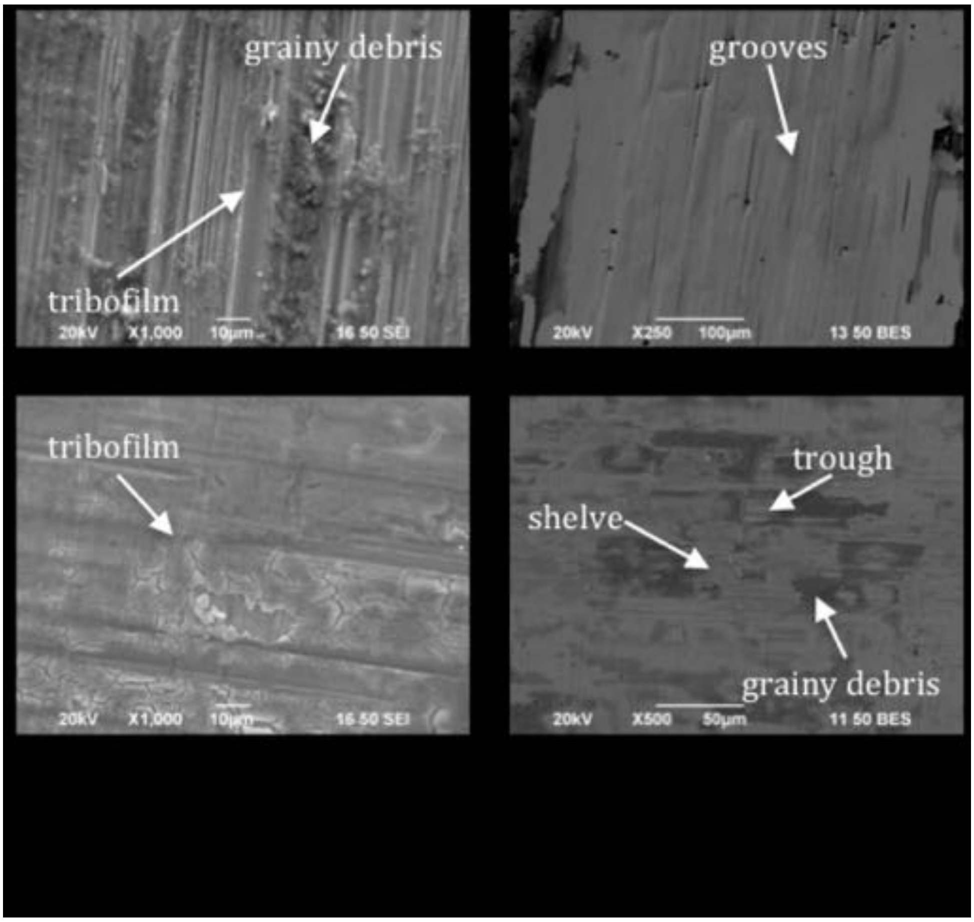

Figure 1

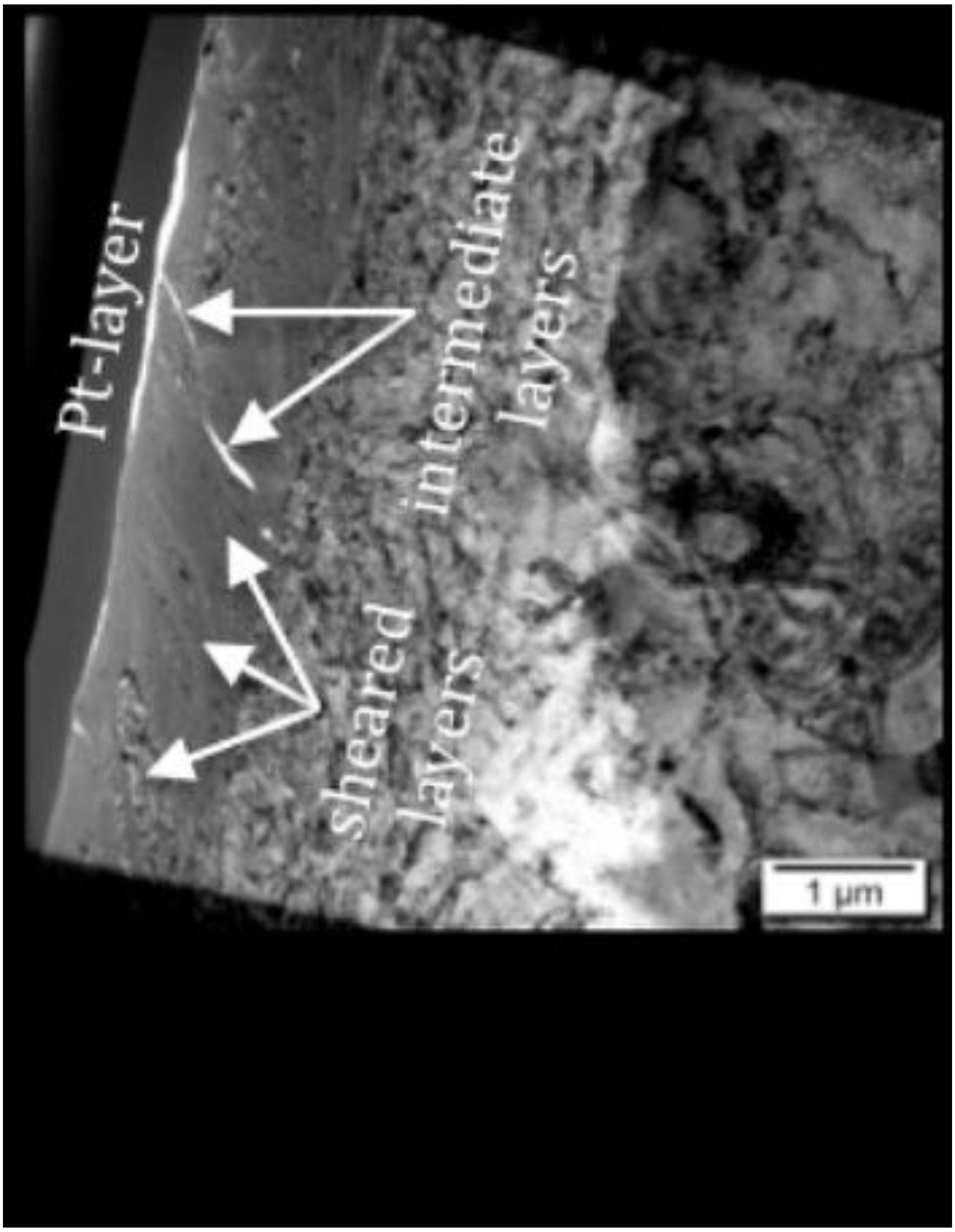

Figure 2

#5972

The Impact of Micro-Motion and Micro-Structure on Modular Junction Corrosion in Hip Replacements

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INTRODUCTION: The lifetime of total hip replacements (THR) is often limited by adverse local tissue reactions to corrosion products generated from modular junctions. Two prominent damage modes are the imprinting of the rougher stem topography into the smoother head taper topography (imprinting) and the occurrence of column-like troughs running parallel to the taper axis (column damage). It was the purpose of this study to identify mechanisms that lead to imprinting and column damage based on a thorough analysis of retrieved implants.

METHODS: 776 femoral heads were studied. Heads were visually inspected for imprinting and column damage. Molds were made of each head taper and scanned with an optical coordinate measuring machine. The resulting intensity images were used to visualize damage on the entire surface. In selected cases, implant surfaces were further analyzed by means of scanning electron microscopy (SEM) and white light interferometry. The alloy microstructure was characterized for designs from different manufactures.

RESULTS: 165 heads exhibited moderate to severe damage (modified Goldberg scale). Out of those heads 83% had imprinting and 28% exhibited column damage. In most cases with imprinting, the entire contact area between stem and head was affected (Figure 1). Several cases exhibited early signs of imprinting, usually starting on the distal-inferior and distal superior side. High resolution SEM imaging revealed that imprinting was a fretting driven process that was independent of the hardness and material of the stem and head. The SEM images showed that the main mechanism was surface fatigue under partial slip fretting. The generated wear debris was the primary driver of imprinting by three-body fretting. The effect was detrimental on the smoother head surface, but less severe on the rougher stem, where debris was pushed into the troughs of the machining mark topography.

90% of cases with column damage also exhibited imprinting. The other ten percent were either cases in which column damage was too extensive to identify imprinting, or the stem taper was smooth and therefore could not induce imprinting. Metallographic analysis showed that column damage was dictated by the alloy microstructure. Wrought alloy heads frequently exhibited banding related to slight alloy segregations. The process of column damage was entirely chemically driven with etching occurring along the banded microstructure eventually resulting in troughs that were several tens of micrometers deep (Figure 2).

DISCUSSION: Imprinting and column damage are common damage modes in THR femoral heads. Imprinting is fretting (miro-motion) driven while column damage is caused chemically, but is also dictated by the alloy micro-structure. However, the results suggest that these two damage modes may be related. The damage process starts with local fretting slowly progressing to a large area of imprinting. The imprinting process leads to widening of the crevice, enabling joint fluid and biological constituents (protein, cells, etc.) to enter the taper interface. This change in local chemistry within a confined crevice environment can cause an etching process that leads to column damage, but only if the femoral head alloy has a banded microstructure.

ACKNOWLEDGEMENT: Funidng by NIH grant R01 AR070181

Figures

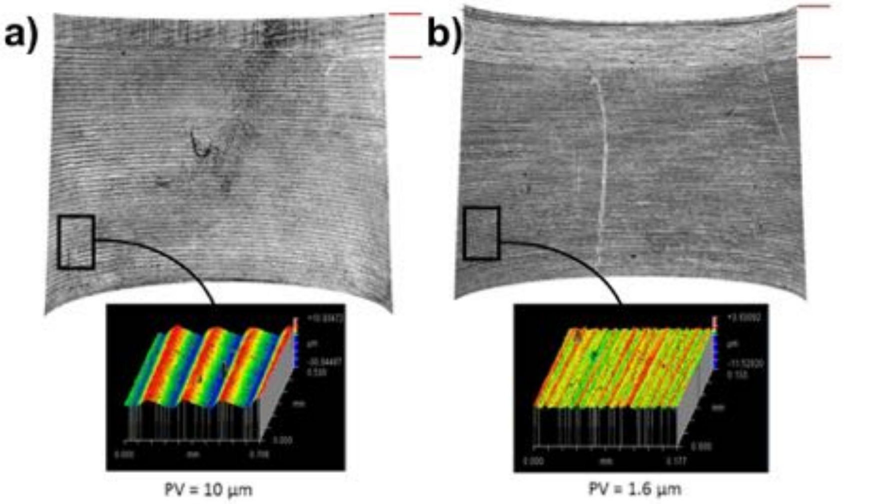

Figure 1 Intensity image and corresponding topography map of two femoral head tapers of the same implant design a) with and b) without imprinting after approx. 5 years in situ. The topography of the head in a) is almost identical to that of its corresponding stem tapers.

Figure 1

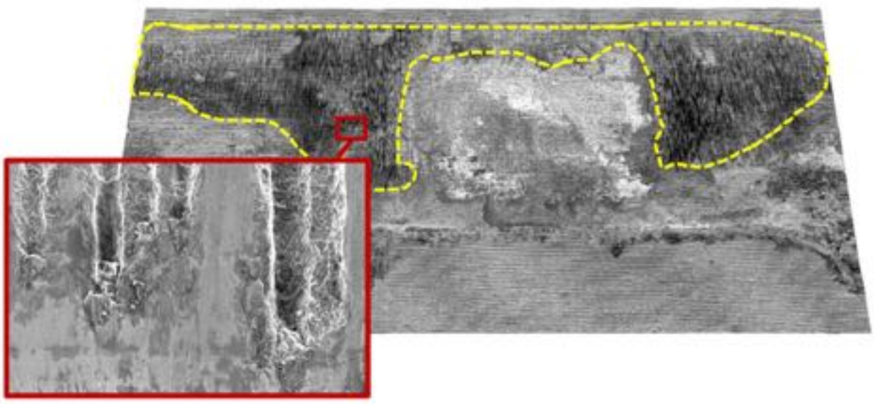

Figure 2 Intensity map of a femoral head taper showing column damage (marked in yellow) covering more than half of the contact area. The close up SEM image (inlet) reveals single troughs within the column damage pattern that area characterized by etching features.

Figure 2

#5662

The Possible Role of the Angular Gap Between Hip Stem Taper and Ball Head and the Stem Taper Profile Depth in Taper Wear and Corrosion

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Introduction

Hip stem taper wear and corrosion is a multifactorial process involving mechanical, chemical and biological damage modes. For the most cases it seems likely that the mechanically driven fretting wear is accompanied by other damage modes like pitting corrosion, galvanic corrosion or metal transfer. Recent retrieval studies have reported that the taper surface topography may affect taper damage resulting from fretting and corrosion [1]. Therefore, the current study aimed to examine effects of different taper topography parameters and material combinations on taper mechanics and results regarding wear and corrosion have been investigated.

Materials and Methods

Combined experimental and numerical studies were conducted using titanium, cobalt-chromium and stainless steel generic tapers (Figure1). Uniaxial tensile tests were performed to determine the mechanical properties of the materials examined. For the taper studies macro-geometry of ceramic ball heads (BIOLOX®*delta*) and tapers were characterized using a coordinate measuring machine, and assembly experiments according to ISO7206-10 were conducted up to 4kN. Before and after loading, taper subsidence was quantified by assembly height measurements. Taper micro-geometry, taper surface deformation, and contact area were determined by profilometry. Initial numerical studies determined coefficients of friction for the three material combinations. Macro- and micro-geometries of the tapers were modelled, and taper subsidence and assembly load served as boundary conditions. Further studies used simplified models to examine effects of varying profile depths and angular gaps on surface deformation, taper subsidence, contact area, engagement length and pull-off force.

Results

Largest coefficient of friction and pull-off forces were calculated for steel (μ=0.32), cobalt-chromium revealed the lowest with μ=0.18. Titanium showed largest deformations and taper subsidence throughout all calculations (Figure2, Figure3). Taper subsidence, engagement length and deformations increased with increasing profile depth while contact area decreased. Pull-off forces were almost constant for different profile depths while they increased for increasing angular gaps. Taper subsidence and deformations also increased with increasing angular gap while engagement length decreased and contact area almost remained constant.

Discussion

In order to decrease wear and corrosion micromotions should be minimized. Therefore, smaller angular gaps and smaller profile depths seems to be beneficial since deformation and taper subsidence are reduced. Literature data confirmed the results for different angular gaps showing that a larger angular gap is associated with larger amounts of micromotion and wear [2, 3]. Additionally, larger angular gaps and larger profile depths result in larger plastic deformation facilitating subsurface crack initiation and propagation. A large angular gap may also facilitate particle release [4]. Larger pull-off forces can indicate larger resistance against micromotion. Therefore, steel may tend to later develop fretting-corrosion in situ. However, among the metals examined steel also showed the largest equivalent plastic strain. This study is limited to pairings involving ceramic heads. These can help mitigating fretting corrosion resulting from micromotion between ball head and cobalt-chromium or titanium alloy tapers [5]. However, future studies will include other ball head materials. In conclusion, this study showed that taper surface topography affects taper mechanics and is important in terms of wear and corrosion.

Figures

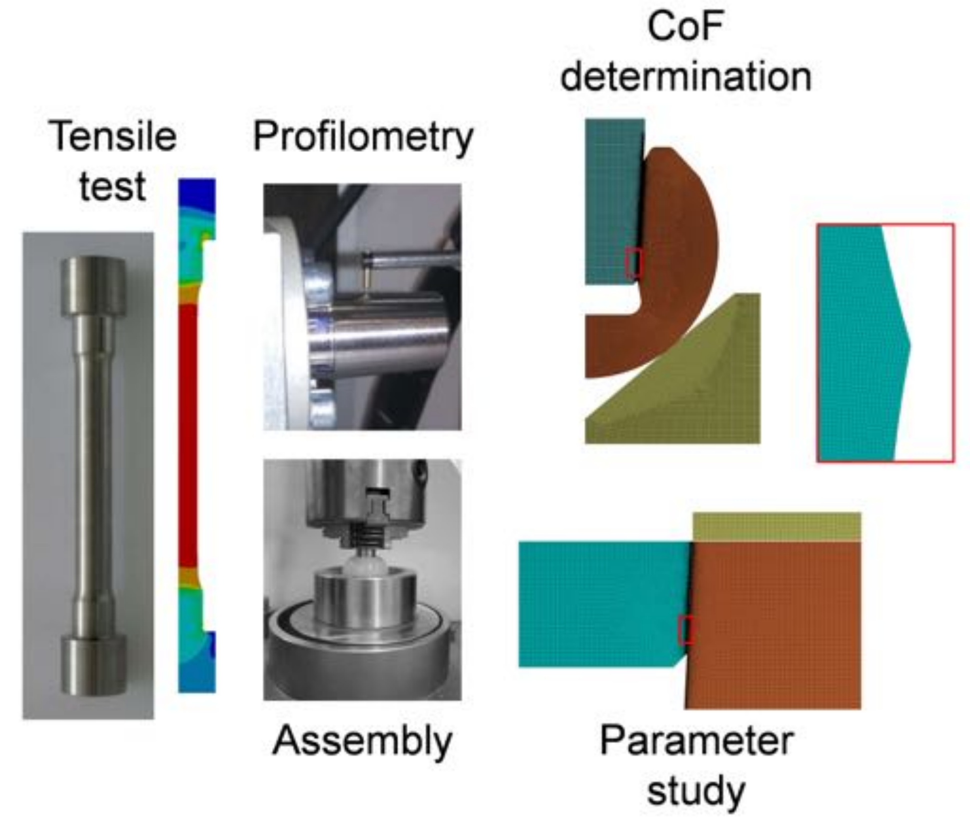

Figure 1: Materials and methods

Figure 1

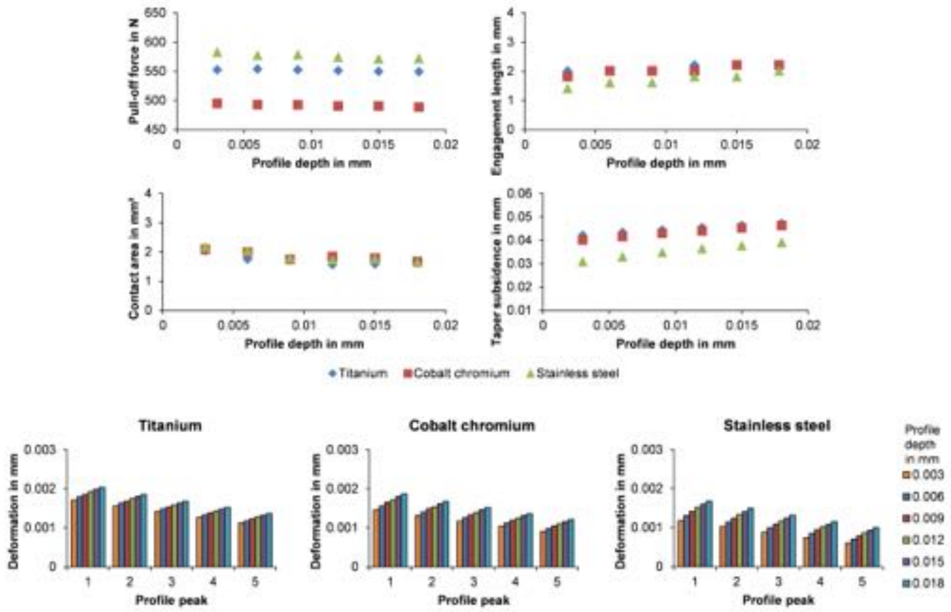

Figure2: Pull-off force, engagement length, contact area, taper subsidence and deformations of the first 5 profile peaks from proximal to distal depending on varying profile depths

Figure 2

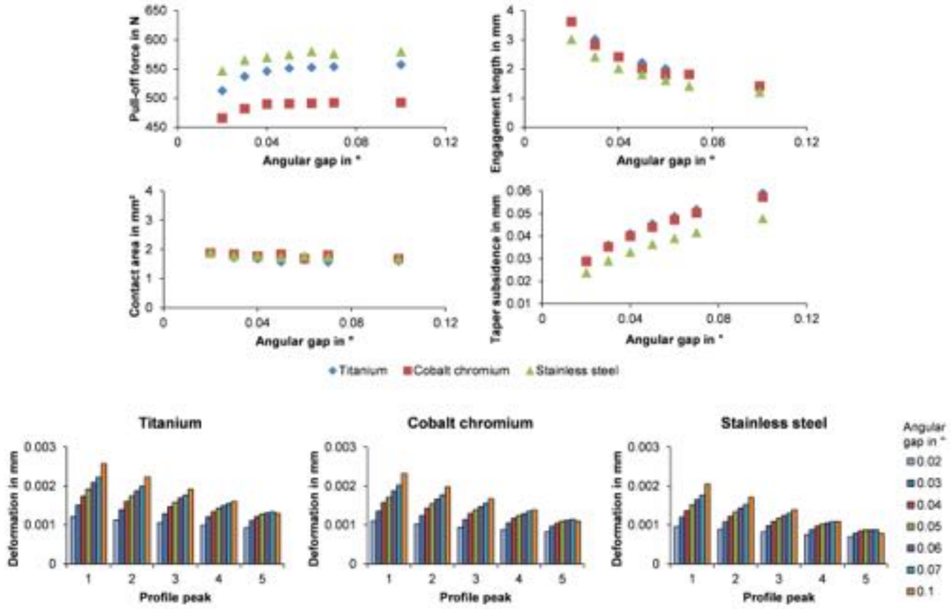

Figure3: Pull-off force, engagement length, contact area, taper subsidence and deformations of the first 5 profile peaks from proximal to distal depending on varying angular gaps

Figure 3

References

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Figure 4

#5772

Utility of Next-Generation Sequencing in the Diagnosis of Periprosthetic Joint Infection

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Introduction: Despite recent advances in the diagnosis of periprosthetic joint infection(PJI), identifying the infecting organism continues to be a challenge, with up to a third of PJIs reported to have negative cultures. Current molecular techniques have thus far been unable to replace culture as the gold standard for isolation of the infecting pathogen. Next-generation sequencing(NGS) is a well-established technique for comprehensively sequencing the entire pathogen DNA in a given sample and has recently gained much attention in many fields of medicine. Our aim was to evaluate the ability of NGS in identifying the causative organism(s) in patients with PJI.

Methods: After obtaining Institutional Review Board approval and informed consent for all study participants, samples were prospectively collected from 148 revision total joint arthroplasty procedures (83 knees, 65 hips). Synovial fluid, deep tissue and swabs were obtained at the time of surgery and shipped to the laboratory for NGS analysis (MicroGenDx). Deep tissue specimens were also sent to the institutional laboratory(Thomas Jefferson University Hospital) for culture. PJI was diagnosed using the Musculoskeletal Infection Society(MSIS) definition of PJI. Statistical analysis was performed using SPSS software.

Results: Fifty-five revisions were considered infected; culture was positive in 40 of these (40/55, 72.7%), while NGS was positive in 47 (47/55, 85.5%). Among the positive cultures, complete concordance between NGS and culture was observed in 33 cases (33/40, 82.5%). One case was partially discordant between NGS and culture, with culture detecting three organisms as opposed to one organism on NGS. One case showed complete discordance with NGS and culture detecting different organisms. Three patients with negative NGS results had positive cultures. In another two cases culture simply reported the gross morphology of the organism but the phenotype was not identified, while NGS was able to definitively identify an organism. Among the 15 cases of culture-negative PJI, NGS was able to identify an organism in 10 cases (10/15, 66.7%). These data are summarized in Figure 1.

Ninety-three revisions were considered to be aseptic; NGS exclusively identified microbes in 15 of 93 “aseptic” revisions (16.1%) and culture exclusively isolated an organism in 4 of 93 cases(5.3%). One case was positive on both NGS and culture, however the results were discordant from each other. The remaining cases (73/93, 78.5%) were both NGS and culture negative. NGS detected several organisms in most positive samples, with a greater number of organisms detected in aseptic compared to septic cases (6.8 vs. 4.0, respectively).

Discussion: NGS was able to detect a pathogen in two-thirds of culture-negative cases and demonstrated a high rate of concordance with culture in culture-positive cases. The rate of false positives was low compared to earlier studies using molecular techniques. Our findings also suggest that some cases of PJI may be polymicrobial and escape detection using conventional culture. NGS may be a useful adjunct for identifying the causative organism(s) in PJI, particularly in the setting of negative cultures. Further study is required to determine the significance of isolated organisms in samples from patients who are not thought to be infected.

Figures

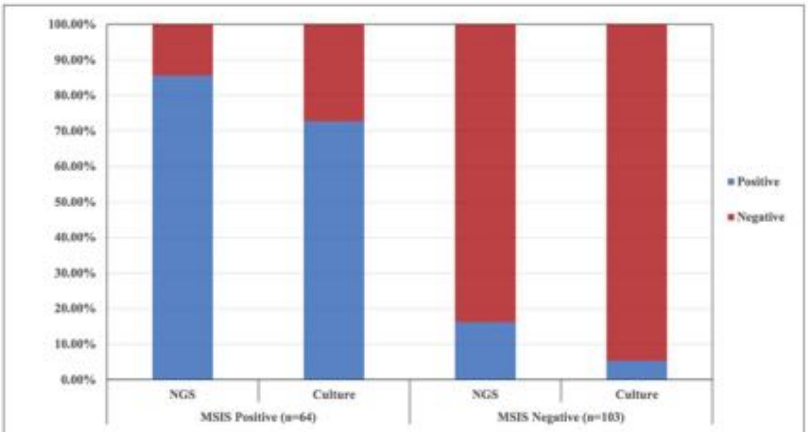

FIGURE 1: Graph showing percentage of positive samples using NGS and culture, in both patients meeting the MSIS criteria and patients who did not meet MSIS criteria.

Figure 1

#5545

Risk Factors for Infection After Total Knee Replacement: Analysis of Patients Who Received Surgery on Same Day by Same Surgeons at a Single Institution

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Purposes: Total knee replacement (TKR)is one of the most successful operations among the established orthopedic surgeries. Nevertheless, infection after TKR is a major complication. Establishment of complete prevention of infection is challenging, in that it is difficult to investigate the various factors that affect risk of infection. We compared infection rates of patients who underwent TKR by the same surgeons at a single institution to investigate infectious risk factors in an environment in which various factors were similar.

Methods: We included 1756 patients who underwent TKR by the same 2 surgeons at a single institution over a 10-year period (2006-2016). In this study, patients who required re-operation due to postoperative infection were defined as the I-group, and patients who underwent TKR on the same day as the I-group but who were without infection were defined as C-group.Age, sex, body mass index (BMI), occupation, laboratory data, operative time, and comorbidities of patients in the I-group were compared with those of the C-group.

Results: The I-group included 10 patients, and the infection rate was 0.57%. The I-group included a statistically significantly higher number of men, of patients with a career in agriculture or a high level of sports activity, and patients who received bilateral TKR on the same day. C-reactive protein (CRP)at the 2-week postoperative visit was significantly higher in the I-group than in the C-group. In 80% of patients in the I-group who received bilateral TKR on the same day, the side on which the operation was performed in the latter half of the day was infected. In addition, 80% of the patients in the I-group underwent surgery in the latter half of the operative day.

Conclusions: After investigation of risk factors for infection after TKR in the same environment, the risk factors included male sex, the side that underwent surgery in the latter half of the day in patients who underwent bilateral TKR on the same day, patients who underwent surgery in the latter half of the day, and patients with careers involving agriculture or sports activity. Our results suggest that infection prevention programs should include close attention to operative devices exposed for a long time and strict attention to the operating room environment in the afternoon.

#5901

Clostridium Difficile Infection: Incidence and Risk Factors in Revision Total Knee Arthroplasty Patients

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Introduction

Revision total knee arthroplasty (TKA) procedures performed secondary to periprosthetic joint infection (PJI) are associated with significant morbidity and mortality. These poor outcomes may be further complicated by the development of postoperative infection requiring aggressive antibiotic treatment. However, this antibiotic overuse may suppress patients' native bacterial flora, leading to *Clostridium difficile* infection (CDI). With the increased demand for primary TKAs and expected rise in revision TKA due to PJI, it is important to identify factors contributing to CDI. Therefore, we aimed to study the: 1) incidence; 2) demographics, length of stay (LOS), and total costs; and 3) risk factors and mortality associated with CDI in revision TKA patients.

Methods

The National Inpatient Sample database was queried for all individuals diagnosed with PJI and who underwent revision TKA between 2009 and 2013. Patients who developed CDI during their in-patient hospital stay were identified, yielding 83,806 patients (799 with CDI) with a mean age of 65 years (SD=11.2 years). Logistic regression analysis was conducted to assess the association between hospital- and patient-specific characteristics and the development of CDI.

Results

During the study period, the overall incidence of CDI after revision TKA was 1.0%. These patients were significantly older (mean age 69.05 vs. 65.52 years) **(Table 1)**, had greater LOS (median 11 vs. 5 days), had greater costs ($30,612.93 vs. $18,873.75) **(Table 2)**, and had higher in-hospital mortality (3.6 vs. 0.5%; p<0.001 for all) compared to those without infection. Patients with CDI were more likely to be treated in urban, not-for-profit, medium or large bed-sized hospitals located in the Northeast or Midwest (p<0.05 for all) **(Table 1)**. Patients with underlying depression (OR 4.267; p=0.007) **(Table 3)** or fluid/electrolyte disorders (OR 3.48; p=0.001) were more likely to develop infection.

Conclusion

Although CDI is a rare event following revision TKA, it can have detrimental consequences. Our report demonstrates that CDI is associated with longer LOS, higher costs, and greater in-hospital mortality. With increased legislative pressure to lower healthcare expenditures, it is crucial to identify means of preventing costly complications.

Figures

Table 1. Incidence and demographics of revision TKA patients with PJI who developed CDI.

	C. difficile infection	No *C. difficile* infection	p-value
Mean Age in Years (SD)	69.05 (12.09)	65.52 (11.22)	<0.001
Median Length of Stay (IQR)	11 (9)	5 (4)	<0.001
Gender			
Male (%)	336 (42.1%)	41,685 (50.2%)	<0.001
Female (%)	462 (57.9%)	41,313 (49.8%)	
Charlson-Deyo Comorbidity score			
0	35 (4.4%)	7,041 (8.5%)	<0.001
1	753 (94.2%)	75,697 (91.2%)	
2	6 (0.8%)	171 (0.2%)	
≥3	5 (0.6%)	98 (0.1%)	
Race			
White	556 (79.4%)	60,816 (81.4%)	0.728
Black	79 (11.3%)	7,145 (9.6%)	
Hispanic	40 (5.7%)	3,948(5.3%)	
Asian/Pacific Islander	5(0.7%)	613 (0.8%)	
Native American	5 (0.7%)	533(0.7%)	
Other	15(2.1%)	1,615 (2.2%)	
Region			
Northeast	174 (21.8%)	15,200 (18.3%)	
Midwest	301(37.7%)	21,587 (26.0%)	
South	203 (25.4%)	31,294(37.7%)	<0.001
West	121 (15.1%)	14,926 (18.0%)	
Hospital Bed Size			
Small	25 (5.7%)	11,975 (14.6%)	<0.001
Medium	205 (26.1%)	20,396 (24.8%)	
Large	535 (68.2%)	49,892 (60.6%)	
Hospital teaching status			
Rural/community	58 (7.4%)	7,103 (8.6%)	
Urban nonteaching	266 (33.9%)	31,994 (38.9%)	0.002
Urban teaching	461 (58.7%)	43,166 (52.5%)	
Control/ownership of hospital			
Government/public	40 (5.1%)	7,811 (9.5%)	
Private, not-for profit	686 (87.4%)	63,223 (76.9%)	<0.001
Private, investor-owned	59 (7.5%)	11,229 (13.7%)	

Figure 1

Table 2. Comparison of in-hospital mortality rates and costs in revision TKA patients with a primary diagnosis of PJI that developed CDI.

	CDI	No CDI	p-value
In-hospital mortality	3.60%	0.50%	<0.001
Median Total Hospital Costs (IQR)	\$30,612.93 (\$22,830.20)	\$18,873.75 (\$13,557.44)	<0.001

Figure 2

Table 3. Forward conditional regression modeling demonstrating factors associated with CDI.

	Odds Ratio	P-value	95% Confidence Interval
Length of stay*	1.249	<0.001	1.114 to 1.363
Alcohol abuse	0.000	1.000	0.000
Depression	4.267	0.007	1.482 to 12.287
Liver disease	7.968	0.076	0.806 to 78.770
Fluid and Electrolyte disorder	3.48	0.001	1.642 to 7.376

*mean-centered length of stay

Figure 3

#5797

Insulin-Dependent Diabetic Patients Are at Increased Risk of Post-Operative Hyperglycemia in Patients Undergoing Total Joint Arthroplasty

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Introduction:

Prosthetic joint infection (PJI) is a devastating complication after total joint arthroplasty (TJA), and diabetic patients are at increased risk of PJI. Insulin is frequently used to achieve glycemic control in patients with a history of poorly controlled diabetes. The link between glycemic control, measured with pre-operative hemoglobin A1c (A1c), and PJI has yet to be firmly established with A1c cutoffs ranging from 7-8%. Further, post-operative hyperglycemia >200mg/dL has been associated with PJI. Despite the abundance of literature on A1c and PJI, the relationship between insulin-dependence and PJI has yet to be investigated. The purpose of this study is to evaluate if insulin-dependent diabetic patients (IDDM) are more susceptible to post-operative hyperglycemia and PJI than their non-insulin-dependent (NIDDM) counterparts.

Methods:

After IRB approval, a retrospective chart review was conducted of all patients undergoing TJA (hip or knee) between January 1, 2011 and December 31, 2016. Inclusion criteria consisted of diagnoses of diabetes mellitus, recorded pre-operative A1c, and minimum of 1-year follow-up. A standardized perioperative regimen was used for post-operative glycemic control, and glucose was measured on morning metabolic panels and finger-stick readings. Patients were stratified into IDDM and NIDDM. Youden's J computational analysis and ROC module was used to determine where A1c values predicted hyperglycemia >200mg/dL for each group. Groups were also compared with a Student's t-test with $p<0.05$ indicating significance. Primary endpoint was post-operative hyperglycemia >200mg/dL and secondary endpoint was PJI.

Results/Discussion:

2317 patients underwent TJA in the study period, with 773 meeting inclusion criteria: 437 IDDM and 336 NIDDM. The IDDM cohort had a higher average pre-operative A1c (6.97% vs 6.28%, $p<0.0001$) and higher post-operative glucose [mean: 235.2 vs 163.5, $p<0.0001$, median: 222 (q1 182, q3 273) vs 147.5 (q1 129, q3 187), $p<0.0001$]. IDDM were more likely to have post-operative hyperglycemia than NIDDM (63.84% vs 20.83%, $p<0.0001$; OR 5.2, 95% CI 3.66-7.4). Accounting for all patients, an A1c of >7.45% was found predict post-operative hyperglycemia (OR 6.94, 95% CI 4.32-11.45), however this was after adjusting for cofounding variables such as insulin dependence. When separating our two cohorts, an A1c of >6.59% in IDDM, and >6.60% in NIDDM, was found to associated with a significantly increased risk of post-operative hyperglycemia ($p<0.0001$). PJI was found to be similar between the IDDM and NIDDM cohorts (2.52% vs 2.38%, $p=0.9034$).

Conclusion:

IDDM undergoing TJA are 5.2-times more likely to have post-operative hyperglycemia >200mg/dL than their NIDDM counterparts which has been associated with PJI in other studies, although this risk of PJI was not found in this study. Despite the higher A1c and post-operative hyperglycemia in IDDM patients, there was found to be no clinical difference between A1c cutoff values for post-operative hyperglycemia between IDDM and NIDDM.

Summary:

Insulin-dependent diabetic patients are at increased risk of post-operative hyperglycemia than those not dependent on insulin, thus caution and strict post-operative glycemic control should be utilized to reduce the risk of complications in these patients.

#6090

Cemented and Uncemented Femoral Fixation Methods in Hip Resurfacing Arthroplasty: A Retrospective Comparison

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Background: The optimal femoral fixation method continues to be debated. To evaluate the role of femoral fixation techniques in hip resurfacing, we present a comparison of the results for two consecutive groups: Group 1 (739 hips) received hybrid hip resurfacing implants with a cemented femoral component; Group 2 (3274 hips) received uncemented femoral components. Both groups received uncemented acetabular components.

Methods: We retrospectively analyzed our clinical database to compare failures, reoperations, complications, clinical results, metal ion test results, and radiographic measurements. All Group 2 patients were at least two years out from surgery. Two-year clinical, radiographic, and laboratory data were compared.

Results: Patient groups matched similarly in T-score, BMI, and percent female. Group 2 was slightly older, on average. The uncemented, Group 2 cases showed a significantly lower raw failure rate (1.2% vs. 4.5% $p<0.0001$), a lower 2-year failure rate (0.8% vs. 2.3%, $p=0.0005$), and a lower rate of femoral complications and failures (0.9% vs. 1.9%, $p=0.016$). In cases that did not fail, patient clinical and pain scores as well as combined range-of-motion, all improved in Group 2 (all $p<0.0001$). 10-year Kaplan-Meier implant survivorship using non-traumatic femoral failure as an endpoint (Figure 1) was 98.2% for the cemented and 99.6% for the uncemented femoral component ($p<0.0001$).

Conclusions: This study demonstrates superior clinical outcomes for cases with uncemented hip resurfacings compared to cases employing hybrid devices. Cases with uncemented stems experienced fewer femoral complications, and the employment of these stems significantly decreased risk of revision due to femoral failure.

Figures

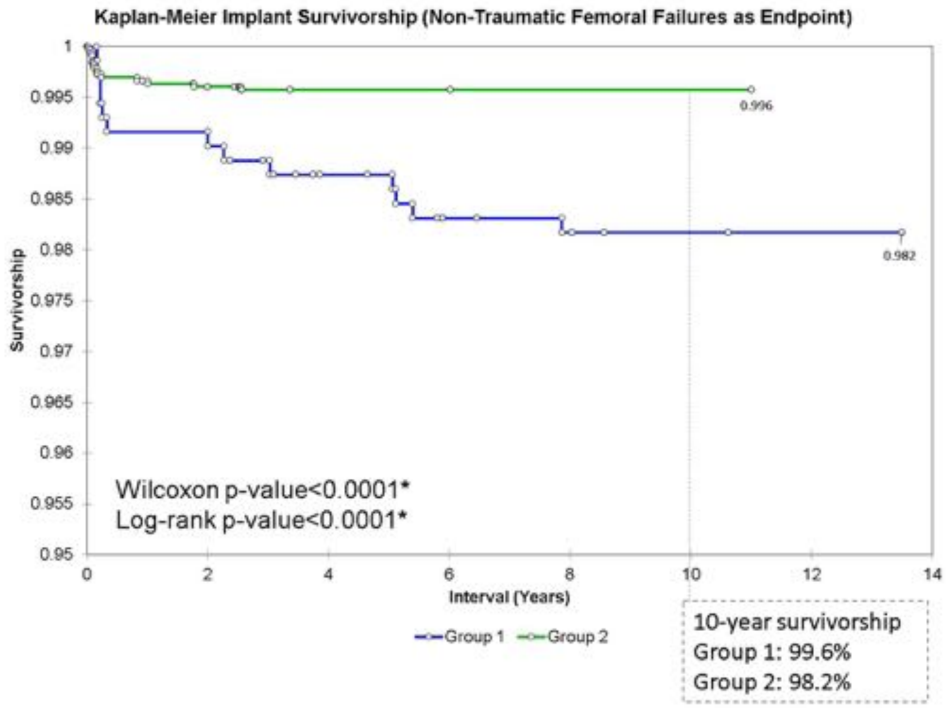
Kaplan-Meier Implant Survivorship (Non-Traumatic Femoral Failures as Endpoint)
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
Survivorship
0.996
0.982
Wilcoxon p-value<0.0001*
Log-rank p-value<0.0001*
0
2
4
6
8
10
12
14
Interval (Years)
Group 1
Group 2
10-year survivorship
Group 1: 99.6%
Group 2: 98.2%

Figure 1

#5805

Gait Analysis Evaluation of the Ability to Resume High Impact Sports in Patients Treated With Hip Resurfacing Arthroplasty

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Background
The aim of this study is to analyse the ability of these patients, treated with MOMHR, to resume sport activities by gait analysis and clinical evaluations.Metal on metal hip resurfacing (MOMHR) is indicated to treat symptomatic hip osteoarthritis in young active patients. These patients require a high level of function and desire to resume sport activities after surgery.

Study Design & Methods
30 consecutive male patients playing high impact sports with unilateral hip osteoarthritis and normal contralateral hip were included in the study, they were treated with MOMHR by the same surgeon. No patients were lost to follow. The mean age at operation was 39.1 years (range 31 to 46). Primary diagnosis was osteoarthritis. OHS, HHS, UCLA activity score were completed at pre-operative time, six months and one year after surgery. Functionally, gait analysis was performed in all patients 6 months and one year after surgery. A stereophotogrammetric system (Smart-DX, BTS, Milano, Italy, 10 cameras, 250Hz) and two platforms (9286BA Kistler Instrumente AG, Switzerland) were used. Cluster of 4 markers were attached on the skin of each bone segment, a number of anatomical landmarks were calibrated and segment anatomical frames defined, markers were positioned by the same operator. Walking, running and squat jump were analyzed and strength and range of movement of the hips and knees were calculated.

Results
At follow-up times the survival rate for the whole cohort was 100%. The mean pre-op OHS was 28.1 points (range 15.0 to 38.0), at 6 months after surgery was 44.5 points (range 44 to 48), at one year after surgery was 47.9 points (range 45 to 48). The mean pre-op HHS was 54.7 points (range 33.1 to 73.4), at 6 months after surgery was 96.7 points (range 93.4 to 100), at one year after surgery was 99.7 points (range 95.7 to 100). The mean pre-op UCLA activity score was 2.7 (range 2 to 4), at 6 months after surgery was 7.4 (range 5 to 10), at one year after surgery was 8.6 (range 7 to 10). At 6 months after surgery, patients showed a reduction of the differences between the operated and the contralateral side during walking, running and squat jumping. ($p<0.01$). One year after the operation there were no differences. At 3 months after surgery the mean hip flexion extension range of motion was in the normal hips 41±1.7 and in the operated hips 37.3±2.1; at 6 months after surgery the mean hip flexion extension range of motion was in the normal hips 45.4±1.8 and in the operated hips 42.0±1.7; At 1 year after surgery the hip flexion extension range of motion was in the normal hips 42.9±1.7 and in the operated hips 45.5±1.4. ($p=0.001$).

Conclusions
Our gait analysis study shows that the biomechanical function of the operated hip is completely recovered 1 year after MOMHR operation. As a consequence sport activities can be successfully resumed. MOMHR is a good choice for young and active patients affected by hip osteoarthritis requiring a high level of activity.

#5807

H1 Anatomic Ceramic Hip Resurfacing: Results of a 20 Patient Safety Study

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Introduction:

We aimed to demonstrate the clinical safety of a novel anatomic cementless ceramic hip resurfacing device. Concerns around the safety of metal on metal arthroplasty have made resurfacing less attractive, while long term function continues to make the concept appealing. Biolox Delta ceramic is now used in more than 50% of all hip arthroplasties, suggesting that it's safety profile is acceptable. We wondered if a combination of these concepts might work?

Materials and methods:

The preclinical testing of anatomic hip resurfacing device developed by our group was presented last year. A twenty patient safety study was designed. Patients had to be between the ages of 18 and 70. The initial size range was restricted to femoral heads between 46 and 54, representing the common sizes of hip resurfacing. The primary outcomes were clinical safety, PROMs and radiological control. Secondary outcomes include CTRSA and metal ion levels.

Results:

20 patients were recruited, aged 30-69. 7 were women and 13 were men. There were no operative adverse events in their operations undertaken between September 2017 and February 2018. One patient had a short episode of atrial fibrillation on the second postoperative day, and no other complications. At three months the median oxford hip score had risen from 27 (range 14-38) to 46 (31-48). Cobalt and chromium levels were almost undetectable at 3 months. Fixation appeared satisfactory in all patients, with no migration detected in either component. CTRSA is in process.

Conclusion:

The initial safety of a novel cementless ceramic resurfacing device is demonstrated by this data. The 10 year, 250 case efficacy study has begun recruiting, and will continue in 5 other European centres. Functional scores suggest that this device may be able to deliver a clinical outcome that is equivalent to a Metal on Metal Hip Resurfacing.

#5565

Good Clinical Outcomes of Hip Resurfacing Patients: Implant Survival, Function, Metal Ion Concentrations, and MARS-MRI Results With a Minimum 10 Years Follow Up

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Introduction

Although intense screening for adverse reaction to metal debris (ARMD) after metal-on-metal (MoM) hip arthroplasty has led to an increased number of revision surgeries in this type of patients; clinical impression is that a substantial number of patients are doing well with long term (>10 year) follow up, especially after hip resurfacing. Since long term results after modern hip resurfacing are scarce, we selected and analyzed from our prospective study cohort with intensive MoM disease screening, all patients who were more than 10 years after index surgery. Our study aim was to evaluate how many patients underwent revision surgery and to evaluate the status regarding hip function, metal ion concentrations, and cross-sectional imaging of all unrevised patients.

Methods

This is a single center prospective cohort study (n=298). From this cohort we were able to include 59 patients >10 years after hip resurfacing. Clinical examination including Oxford Hip Scores (OHS; excellent: <19, good: 19-26, fair: 27-33; poor: >33) were collected yearly up to 5 years and then at 7, 10, and 12 years after surgery. Starting 2012 we intensified our follow up in response to the attention for MoM disease, with routine metal ion concentrations (>7ppb considered abnormal) and metal artefact reducing sequence (MARS)-magnetic resonance imaging (MRI). With MARSMRI we used the Anderson classification (C1, C2, and C3 indicating MoM disease). Descriptive statistics and a Kaplan Meier survival curve were used to analyse results.

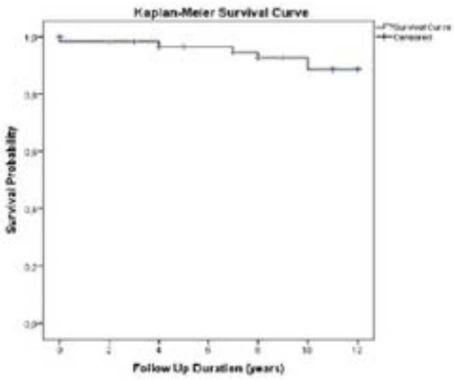
Results

Fifty-nine Patients >10 years after hip resurfacing were identified. Of these 59 patients, 6 were revised (10.2%), 6 were deceased (10.2%), and 3 were not available for follow up (5.1%), leaving 44 procedures for analysis (74.5%). Mean age at surgery was 54.2 years (34-71), 35 were male, and follow up ranged from 10.1 to 12.3 years. Kaplan-Meier survival at 12 years was 90.1 (see figure 1). Some 73% had normal MARS-MRI, 22.7% had mild MoM disease (Anderson C1) on MARS-MRI, and 4.3% had moderate MoM disease (Anderson C2) on MARS-MRI. At the latest follow up, mean OHS score was 15.7 points (Excellent= 78%; Good= 14.6%; Fair= 4.9; Poor= 2.4%). Of the patients with an excellent/good OHS score, 1 had Chrome >7ppb but normal MRI. Two asymptomatic patients with normal metal ion concentrations had moderate MoM disease on MARS-MRI. All unrevised patients with abnormal MARS-MRI results underwent repeated MARS-MRI, and in all these cases these MoM abnormalities were unchanged over time.

Discussion and conclusion

The majority of patients with a hip resurfacing prosthesis in situ >10 years are doing well when followed up clinically with metal ion analysis and MARS-MRI. However silent MoM diseases is present in selected cases, requiring accurate follow up.

Figures



[Figure 1]()

Asymptomatic Early Cup Shifts in Hip Resurfacing Arthroplasty

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Background: While developing protocols for increased control of acetabular component position in hip resurfacing arthroplasty, we instituted a policy to obtain standardized anterior-posterior pelvis x-rays in surgery and immediately postoperatively. With these radiographs, we began to notice asymptomatic acetabular component shifts on standardized 6-week follow-up x-rays when compared to initial intraoperative implant position.

Methods: The purpose of this study was to first characterize the previously undescribed phenomenon of early cup shifts, to study the factors that cause it, and to report the 2-year outcome of these cases. We evaluated whether changing the initial cup position or if acetabular bone preparation was related to this complication. In Group 1 we under reamed 1mm in all cases. In Group 2 we instituted a bone preparation protocol that created a “wedge-fit” to test whether this would increase cup stability. First, reaming was adjusted by bone density. In “soft bone” (T-score <-1.0), we under-reamed acetabulae by 1-mm less than the outer diameter of the cup. For all other T-scores, we now reamed line-to-line. Second, we performed an “apex relief” in all cases by removing 2 mm of apex bone with a small reamer after the largest reamer was used. This new protocol was implemented by March 2012. Herein, we compare cases before (Group 1) and after (Group 2) this date.

Results: We have recognized an 0.84% incidence (25 of 2960 cases) of cup shifts between December 2007 and June 2016. Four (16%) occurred the first time the patient walked, the remainder developed within 6 weeks postoperatively. Of those that shifted before 6 weeks, 10 (47.6%) were missing immediate postoperative standing x-rays; therefore, it is unknown if they shifted the first time the patient walked. In 4 cases (16%) the cup was repositioned intraoperatively. Cup repositioning did not affect the rate of cup shift (p=0.15). In all cases, the acetabular component moved into a more horizontal position. All cups became stable radiographically after the initial shift. One case required revision after 4 years for symptoms of impingement. All other cases functioned well and were asymptomatic. None developed problematic ion levels or adverse wear-related failure. Final HHS and pain score were no different whether the cup shifted or not (p=0.74 and p=1.0, respectively). With the “wedge -fit “acetabular preparation method cup shifts occurred less frequently; 1.2% in Group 1 (14/1175 cases) and 0.4% in Group 2 (7/1598 cases) (p=xx). Demographics were similar between Group 1 and 2; and there was no difference in rate of intraoperative cup repositioning.

Conclusions: Uncemented acetabular components exhibit asymptomatic shifts in position in 0.84% of cases typically into a more horizontal position which rarely poses a problem for hip resurfacing arthroplasty. We only began noticing this phenomenon after initiating a protocol of standardized intraoperative radiographs. Intraoperative cup repositioning does not affect final cup stability. Employing a “wedge-fit” preparation method improves initial cup stability.

#5775

Polymyxin and Bacitracin in the Irrigation Solution: There Is No Role for This Practice

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Introduction: The use of irrigation solution during surgical procedures is a common and effective practice in reduction of bioburden and the risk of subsequent infection. The optimal irrigation solution to accomplish this feat remains unknown. Many surgeons commonly add topical antibiotics to irrigation solutions assuming this has topical effect and eliminates bacteria. The latter reasoning has never been proven. In fact a few prior studies suggest addition of antibiotics to irrigation solution confers no added benefit. Furthermore, this practice adds to cost, has the potential for anaphylactic reactions, and may also contribute to the emergence of antimicrobial resistance. We therefore sought to compare the antimicrobial efficacy and cytotoxicity of irrigation solution containing polymyxin-bacitracin versus other commonly used irrigation solutions.

Methods: Using two *in vitro* breakpoint assays of *Staphylococcus aureus* (ATCC#25923) and *Escherichia coli* (ATCC#25922), we examined the efficacy of a panel of irrigation solutions containing topical antibiotics (500,000U/L Polymyxin-Bacitracin 50,000U/L; Vancomycin 1g/L; Gentamicin 80mg/L), as well as commonly used irrigation solutions (Normal saline 0.9%; Povidone-iodine 0.3%; Chlorhexidine 0.05%; Castile soap 0.45%; and Sodium hypochlorite 0.125%) following 1 minute and 3 minutes of exposure. Surviving bacteria were counted in triplicate experiments. Failure to eradicate all bacteria was considered to be "not effective" for that respective solution and exposure time.

Cytotoxicity analysis in human fibroblast, osteoblast, and chrondrocyte cells exposed to each of the respective irrigation solutions was performed by visualization of cell structure, lactate dehydrogenase (LDH) activity and evaluation of vital cells. Toxicity was quantified by determination of LDH release (ELISA % absorbance; with higher percentage considered a surrogate for cytotoxicity). Descriptive statistics were used to present means and standard deviation of triplicate experimental runs.

Results: Polymyxin-Bacitracin, Saline and Castile soap irrigation at both exposure times were not effective at eradicating *S aureus* or *E coli* (Figure 1). In contrast, Povidone-iodine, Chlorhexidine, and Sodium hypochlorite irrigation were effective at eradicating both *S aureus* and *E coli*. Vancomycin irrigation was effective at *S aureus* eradication but not against *E coli,* whereas Gentamicin irrigation showed partial efficacy against *E coli* eradication but none against *S aureus.*

The greatest cytotoxicity was seen with Chlorhexidine (49.4% ± 1.9). This was followed by Castile soap (33.2% ±3.9), Vancomycin (9.01% ±5.1), Polymyxin-Bacitracin (8.45%

±1.5), and Gentamicin irrigation (4.72% ±2.3) (Figure 2 and Figure 3 microscopy images). Povidone-iodine and Sodium hypochlorite showed least cytotoxicity (0.05% ±0.08 and 0.11% ±0.19, respectively). Similar trends were seen at both exposure times and across fibroblasts, osteoblasts and chondrocytes.

Discussion: This *in vitro* study suggests that addition of polymyxin-bacitracin to saline irrigation solution is a futile exercise. Taken within the context of its associated expense, risk of hypersensitivity and impact upon antimicrobial resistance, our findings bring its widespread clinical usage into question. Povidone-iodine may be a more effective option, with a more favorable cytotoxicity profile than the other commonly used irrigation solutions. Clinical outcomes should be studied to determine the most effective agent, concentration, and exposure time for intraoperative irrigation.

Figures

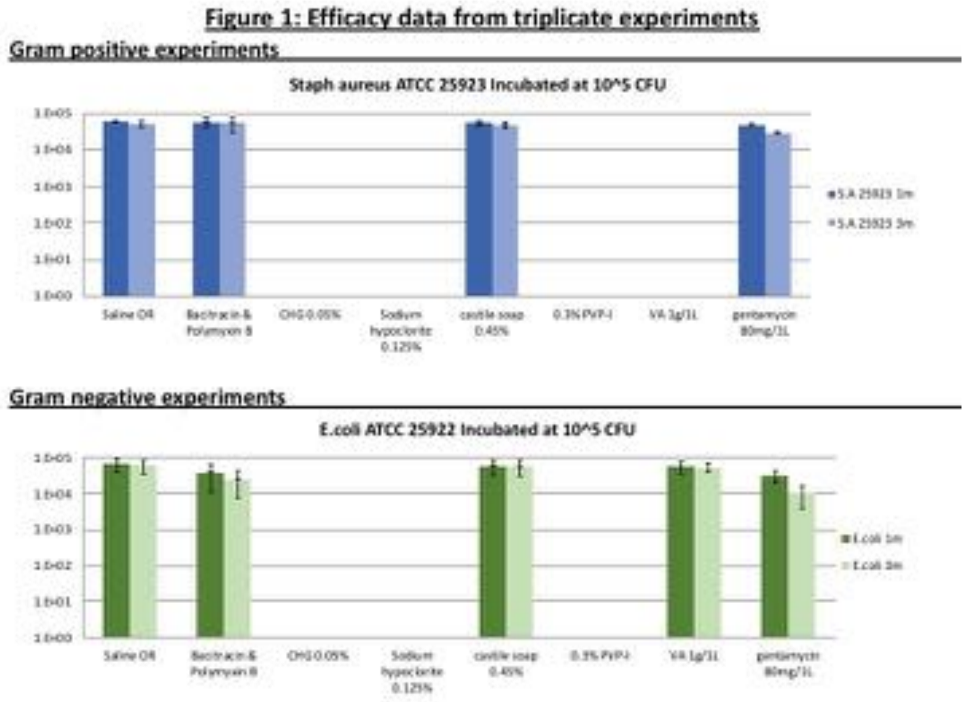

Figure 1

Figure 2: Cytotoxicity Data from triplicate LDH assay experiments in Osteoblasts

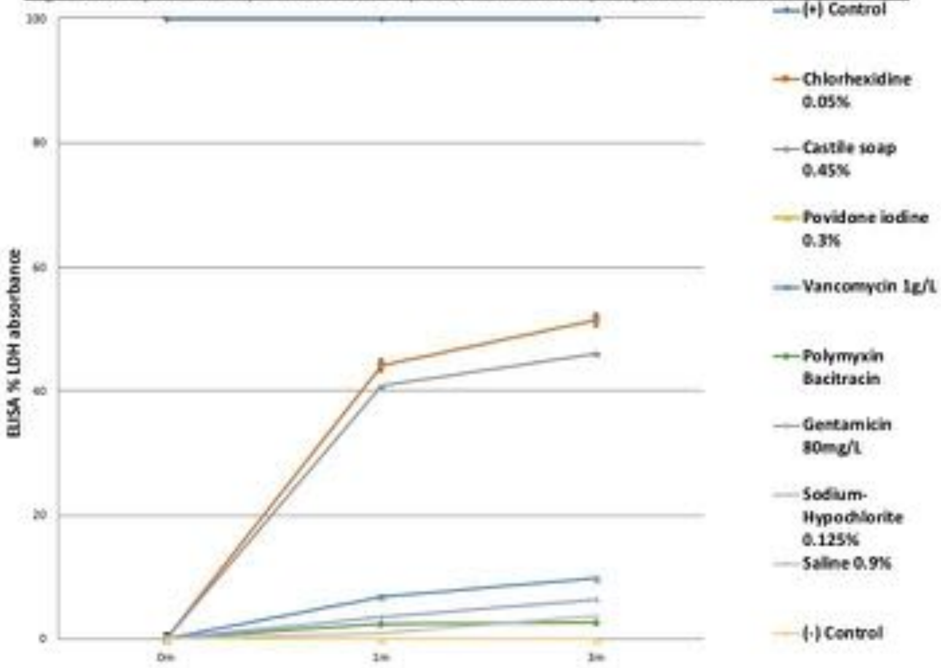

Figure 2

Figure 3: Microscopy Cytotoxicity Fibroblasts

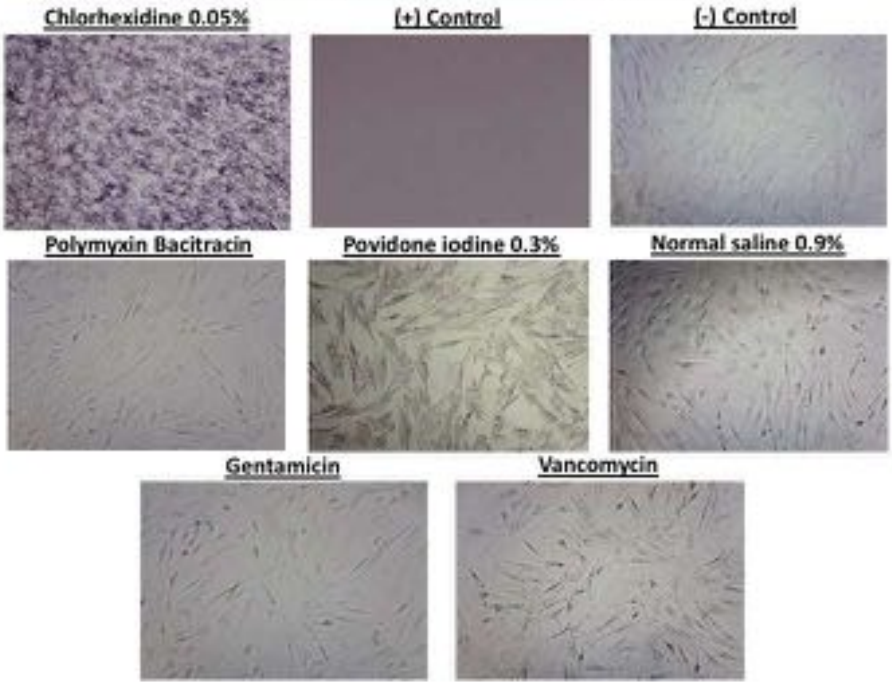

Figure 3

Bactericidal Activity of Gallium-Doped Chitosan Coatings Against Staphylococcal Infection

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Post-arthroplasty infection is one the main issues after total joint replacement surgery. The conventional solutions result in long term antibiotic use and hosting the patient in the hospital. Biofilm can happen when microorganisms attach to a surface. Many different types of microorganisms, including bacteria and fungi, are able to form biofilm. Most of the clinical infections are biofilm-based (Up to 80%).

According to the latest findings, the number of post-arthroplasty infections will increase to more than 266,000 cases a year which would be detrimental for the healthcare resources and will significantly increase medical costs. To promise a novel method to tackle this issue, we applied Chitosan (CS)/gallium (Ga) composite coating to surfaces, which was prepared by electrophoretic deposition (EPD). After studying the morphology of the coatings and finding the optimum conditions for uniform coating, the releasing profile of Ga in different concentrations were studied, as Ga results in bactericidal activity. We assessed biofilm formation and cell growth in the presence of the composite-coated surfaces by *Staphylococcus epidermidis and Staphylococcus aureus* which are the main strains of bacteria that causes post-arthroplasty infections. Cell viability was assessed using Alamar Blue™ assay and biofilm formation was investigated by counting colony-forming units (CFU) and crystal violet assay.Finally, the invitro influence of Pulsed Electromagnetic Field (PEMF) is investigated on modification of bactericidal activity of the CS/Ga composite coatings. The coatings incubated into S. epidermidis strain 14990 and S. aureus strain 12600 were exposed to the PEMF at two different frequencies, 40,850 Hz as the high frequency and 3,846 Hz as the low frequency, for 15 minutes and 4 hours. The biofilm viability decreased up to 80-90% in *S. epidermidis* samples (see Figure 1) which were exposed to high and low frequency PEMF respectively. This number were 82-84% for the *S. aureus* samples (see Figure 2). The electrophoretic deposition of CS/Ga composite coating on orthopaedic implants show excellent bactericidal activity as well as biocompatible properties. Furthermore, the polymer-antibacterial agent (Ga) implant coating evaluated in this study was effective, suggesting the potential for this strategy as a therapeutic intervention to combat post-arthroplasty infections. Increasing concentrations of Ga loaded into CS matrix within the chemically bound coating reduces biofilm viability by up to 86% and 80% in *S. epidermidis* and *S. aureus* strains respectively. This novel coating could reduce the incidence of infection in orthopaedic implant applications.

Keywords: electrophoretic deposition (EPD) ; chitosan (CS) ; gallium (Ga) ;staphylococcus epidermidis; staphylococcus aureus; post-arthroplasty infection; PEMF.

Figures

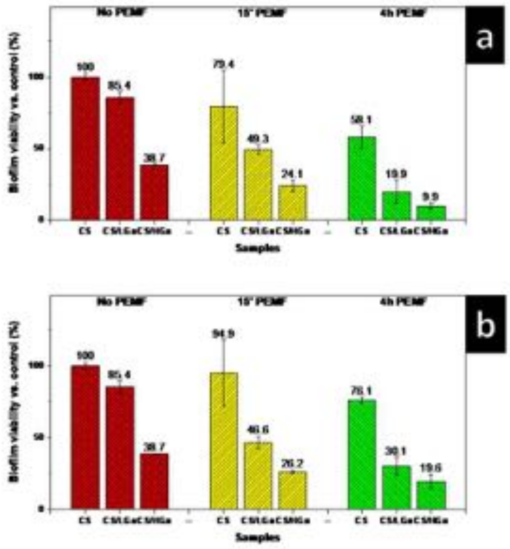

Figure 1. PEMF impact on biofilm viability of *S. epidermidis* strain 14990 in EPD CS/Ga composite orthopaedic coating; after 24h; (a) at low frequency, (b) at high frequency (all the absorbance values are normalized to no PEMF CS value).

Figure 1

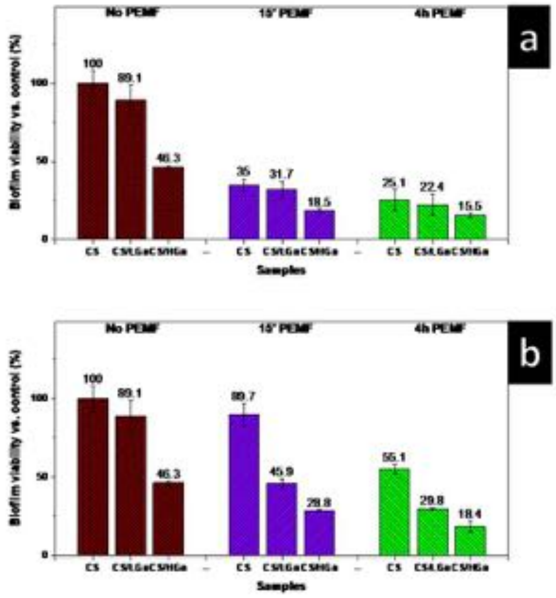

Figure 2. PEMF impact on biofilm viability of *S. aureus* strain 12600 in EPD CS/Ga composite orthopaedic coating; after 24h; (a) at low frequency, (b) at high frequency (all the absorbance values are normalized to no PEMF CS value).

Figure 2

#5954

Cathodic Voltage Controlled Electrical Simulation for Treatment of Periprosthetic Joint Infections

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Introduction: Periprosthetic joint infection (PJI) remains a difficult clinical challenge. Cathodic voltage-controlled electrical stimulation (CVCES) of -1.8V vs Ag/AgCl applied directly to titanium (Ti) implants for 1 hour has been shown to reduce the bacterial burden of methicillin-resistant *Staphylococcus aureus* (MRSA) PJI in an in-vivo model. The present in-vitro study evaluated the effectiveness of extended duration and/or lower magnitude CVCES, either alone or in combination with antibiotic therapy, to eradicate bacterial biofilms of select ESKAPEE pathogens pre-formed on Ti coupons.

Methods: The bacterial strains utilized in these tests included Gram-positive MRSA (clinical isolate NRS70), Gram-negative *Acinetobacter baumannii* (clinical isolate Ab307) and Gram-negative *Pseudomonas aeruginosa* (ATCC PA27853). Sterile Ti coupons were incubated with fresh bacterial cultures for 18 hours to allow for bacterial attachment and formation of biofilm-like structures on the coupon surface. The coupons were subsequently mounted in a custom 3-electrode test chamber, designed to simulate tissue coverage of an orthopedic implant, and CVCES was applied directly to the Ti coupons for 24 hours. Experiments were conducted for different CVCES magnitudes (open circuit potential, -1.0V, -1.5V, and -1.8V vs Ag/AgCl) in the absence or presence of antibiotics (0.5mg/mL vancomycin for NRS70, 1mg/mL amikacin for Ab307, and 3mg/mL gentamicin for PA27853) in the surrounding culture media. Immediately following the incubation/treatment period the Ti and the surrounding culture media were harvested and prepared for dilution plating to enumerate colony-forming units (CFU) of viable coupon-associated and planktonic bacteria. The experimental groups included controls (no CVCES and no antibiotics), antibiotics only , CVCES only, or combined CVCES and antibiotics. A minimum of four independent samples were conducted for each experimental group for each CVCES magnitude and bacterial strain.

Results: The control groups all had a robust coupon-associated and planktonic bacterial burden (~10^7 to 10^9 CFU/mL). The antibiotics alone showed 2-6 log reductions in planktonic CFU, with a more modest 1-2 log reduction of coupon-associated CFU. Voltage-dependent reductions in the coupon-associated and planktonic CFU occurred for all bacterial strains tested. The application of CVCES at -1.8V for 24hr, both in the presence and absence of antibiotics, produced a greater than 7 log reduction, and in many samples complete eradication, of both the coupon-associated and planktonic bacterial burden. CVCES alone at -1.5V showed 1-2 log reductions of both coupon-associated and planktonic CFU, while CVCES alone at -1.0V showed no reductions in CFU. Synergistic reductions in coupon-associated CFU (3-7 log reduction) and planktonic CFU(4-8 log reduction) were reported when CVCES at -1.5V was combined with antibiotic treatment.

Significance: These findings suggest that combining CVCES at cathodic potentials of -1.5V or greater with clinically appropriate antibiotics may provide an effective and broad-spectrum strategy for eradicating the implant and adjacent tissue bacterial burden associated with PJI. Ongoing studies are evaluating this combined treatment approach in an in-vivo model of PJI.

#5745

In Vivo Anti-Bacterial Effectiveness of Nanotextured Titanium Implant Surfaces

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Periprosthetic infection remains a clinical challenge that may lead to revision surgeries, increased spending, disability, and mortality. The cost for treating hip and knee total joint infections is anticipated to be $1.62 billion by 2020. There is a need for implant surface modifications that simultaneously resist bacterial biofilm formation and adhesion, while promoting periprosthetic bone formation and osseointegration.

In vitro research has shown that nanotextured titanium promotes osteoblast differentiation, and upregulates metabolic markers of osteoblast activity and osteoblast proliferation. *In vivo* rat studies confirmed increased bone-implant contact area, enhanced *de novo* bone formation on and adjacent to the implant, and higher pull-out forces compared to non-textured titanium. The authors have advanced a benign electrochemical anodization process based on ammonium fluoride that creates a nanotube surface in as little as 10 minutes (Fig. 1), which can also integrate antibacterial nanosilver (Fig. 2).

The work reported here summarizes *in vitro* post-inoculation and *in vivo* post-implantation studies, showing inherent inhibition of methicillin-resistant *Staphylococcus aureus* (MRSA) by titanium surfaces with nanotubes (TiNT), nanotubes with nanosilver (TiNT+Ag), plain (Ti), and thermal plasma sprayed (TPS) titanium. Ti6Al4V was the base material for all surfaces. *In vitro* studies evaluated Ti, TPS, four TiNT groups with varying nanotube diameters (60nm, 80nm, 110nm, 150nm), and TiNT+Ag. After seeding with MRSA (10^5, 10^6, and 10^8 CFU/mL), the 110nm diameter nanotubes showed MRSA inhibition up to three-orders of magnitude lower than the Ti and TPS surfaces at 2, 6, and 48 hours.

Following on the *in vitro* results, New Zealand White rabbits underwent a bilateral implantation of intramedullary tibial implants of the four material groups (4 mm outside diameter; 110nm NT diameter on TiNT and TiNT+Ag implants). One intramedullary canal was inoculated with clinically-derived MRSA (10^5 CFU in broth) at the time of implantation; one canal had only culture media introduced (control). At a 2-week endpoint, limbs were harvested for analysis, including implant sonication with sonicant bacterial cultured, histology, and microcomputed chromatography. In the sonicant analysis cohort, TPS showed the lowest average MRSA count, while TiNT and TiNT+Ag were the highest. There was one sample each of TPS, TiNT and TiNT+Ag that showed no MRSA. After an additional 24-hour implant incubation, the TiNT and TiNT+Ag samples had no bacteria, but the TPS grew bacteria; therefore, the authors hypothesize that MRSA more readily releases from the TiNT and TiNT+Ag implants during sonication, indicating weaker biofilm adhesion and development. Histologic analysis is currently underway. In a therapeutic experiment, rabbits underwent bilateral implantation, followed by 1 week of infection development, and then 1 week of vancomycin treatment. At the endpoint, implants were sonicated and bacteria was quantified from the sonicant. TiNT showed viable MRSA at only 30% that of TPS-coated levels, while TiNT+Ag implants showed viable MRSA at only 5% that of TPS-coated levels (Fig. 3). These early results indicate that the TiNT and TiNT+Ag surfaces have some inherent antibacterial activity against MRSA, which may increase the efficacy of systemic antibiotic treatments in the setting of periprosthetic joint infections.

Figures

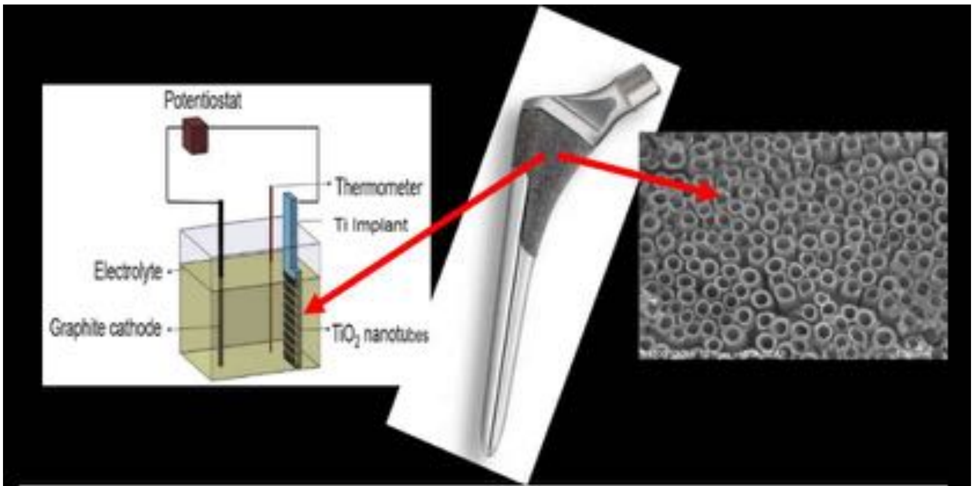

Fig 1. Anodization process for creating nanotubes in any titanium implant surface.

Figure 1

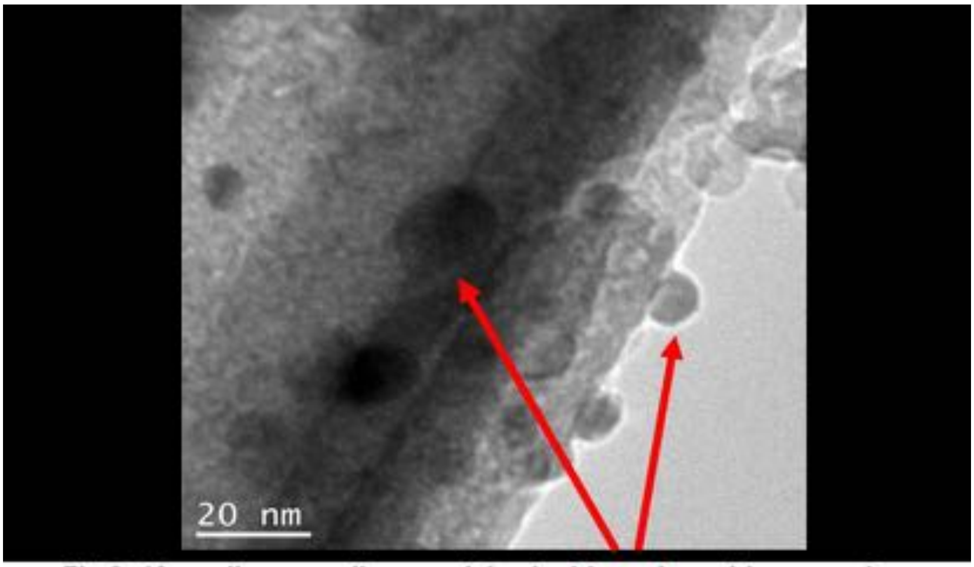

Fig 2. 10nm diameter silver particles inside and outside nanotubes.

Figure 2

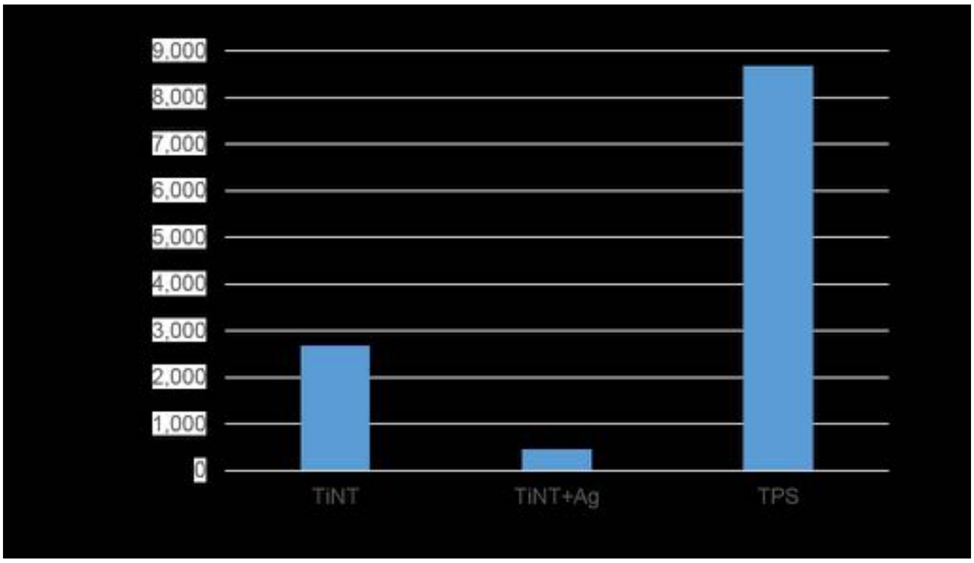
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
TiNT
TiNT+Ag
TPS

Figure 3

#5956

Mechanical Analysis of Tigecycline Loaded Bone Cement and Comparison With Vancomycin and Daptomycin Loaded Bone Cements

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Background: Tigecycline, the first member of glycylcycline family, has effective antimicrobial activity against resistant and implant associated infectious organisms. The objectives of this study are to assess the compressive and tensile mechanical strength characteristics of tigecycline loaded bone cement and to compare them with vancomycin and daptomycin loaded bone cements which are used in prosthetic joint infections with resistant microorganisms.

Methods: A control group without antibiotics and three antibiotic loaded bone cement groups with varying concentrations were prepared and tested according to ASTM F451 and ISO 5833 standards. Statistical analysis of the obtained data done by using LSD (least significant difference) and Bonferroni corrected Mann Whitney tests.

Results: Both compression and tension tests showed that all determined antibiotic concentrations resulted in significant decrease when compared to the control group. Despite heterogenous statistical results, it was seen that the mechanical strength of tigecycline loaded bone cement was not significantly lower (even higher in some comparisons) when compared to vancomycin and daptomycin loaded bone cements.

Conclusion: When used at defined concentrations, tigecycline loaded bone cement does not have mechanical disadvantage compared to vancomycin and daptomycin loaded bone cements. Thus, it should be kept in mind as an option in appropriate clinical situations.

Figures

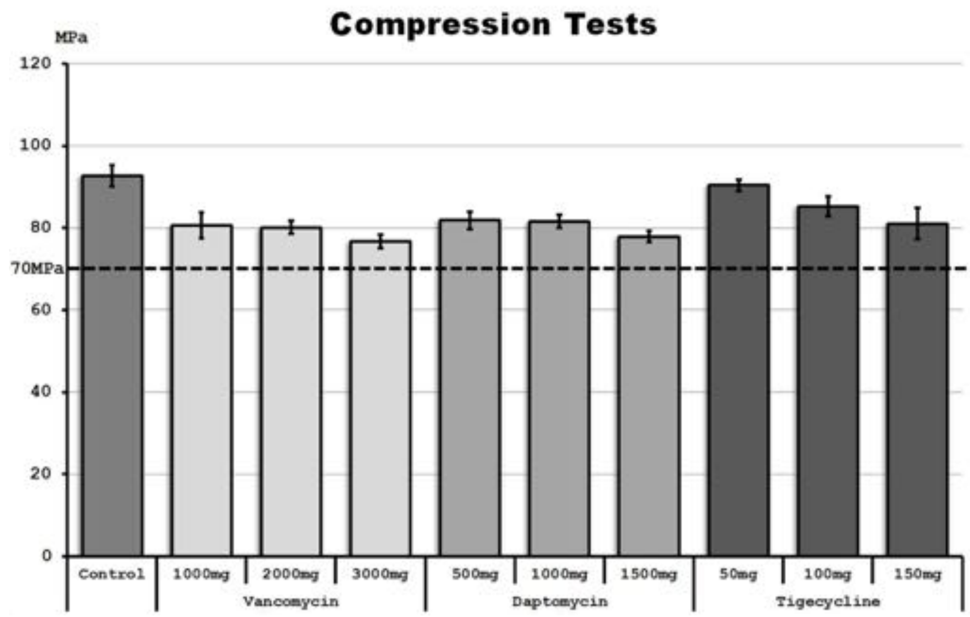

Figure 1

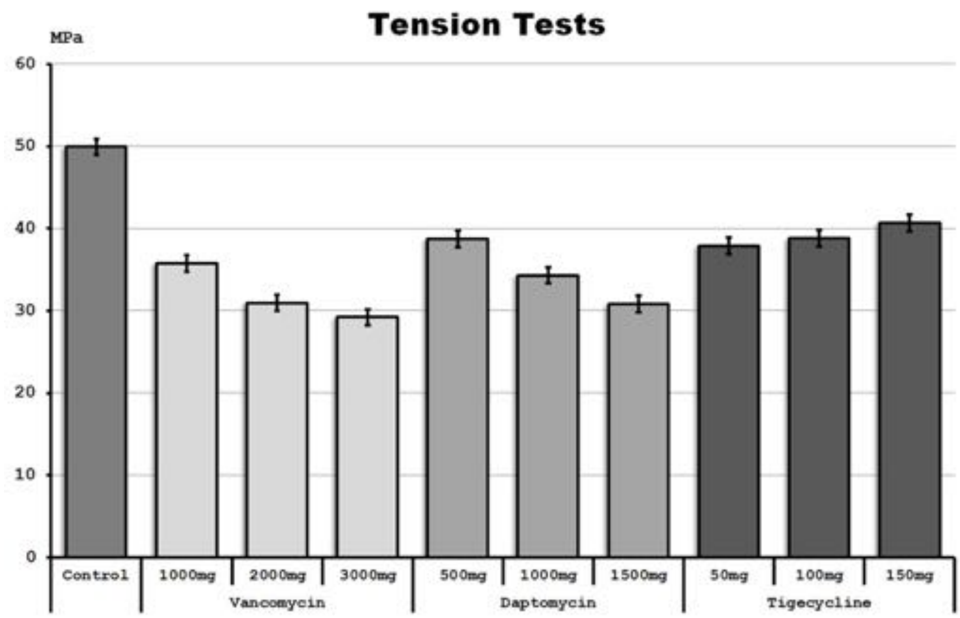
Tension Tests
MPa
60
50
40
30
20
10
0
Control
1000mg
2000mg
3000mg
500mg
1000mg
1500mg
50mg
100mg
150mg
Vancomycin
Daptomycin
Tigecycline

Figure 2

#5841

Computer Assisted Revision Hip Arthroplasty: Short-Term Advantages Versus Long-Term Evidence

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Introduction: Revision total hip arthroplasty (THA) is a technically demanding procedure. Complications such as dislocation, intraoperative fracture, and nerve palsy occur more often after revision THA than after primary THA. The proper preoperative planning and preparation for necessary implants, bone graft or substituting materials and supportive instrumentation are important to minimize these complications and to improve clinical outcomes. Computed tomography (CT)-based navigation systems are thought to be beneficial for planning and intraoperative guidance for proper implant alignment. Although there are several reports on the efficacy of CT-based navigation systems in primary THA, usefulness of application for revision THA remain unclear. The purpose of this study was to evaluate the short-term advantages of CT-based navigation for revision THA and the survivorship of implants at 10 years.

Materials and Methods: Fifty patients who underwent revision THA due to aseptic loosening or recurrent dislocation by a single surgeon through a posterior approach using CT based navigation (Stryker CT-based hip navigation system; Stryker, Freiburg, Germany) from July 2007 to May 2015 were enrolled in this study and their medical record and radiographs were retrospectively reviewed. There were 47 females and 13 male. The average age at operation was 65 years. Based on CT-based preoperative planning, 38 cementless cups were used in cases with sufficient bone stock like Paprosky I or II defects and twelve cemented polyethylene cups were used with a support ring or cage and bone grafting in the remaining cases with Paprosky III severe bone defects. The alignment of cementless cups and cemented cups were navigated to aim 40 degrees of radiographic inclination (RI) to the functional pelvic plane in supine. The target cup anteversion (RA) was 20 degrees +/- 10 degrees according the stem anteversion.

Results: The minimum two year follow-up was completed in all cases and the average follow-up term was 5.0 years (2 – 11 years). There were no nerve palsy, infection, or dislocation. The average JOA hip score was significantly improved from 55 to 88. According to the radiographic evaluation, there was no loosening of the implant. Postoperative mean cup alignment was 42 degrees of RI and 16 degrees of RA.

Discussion and conclusions*:* CT-based navigation has two major benefits in revision THA. CT-based preoperative planning is a powerful tool to evaluate the bone defects and the reconstruction method can be optimized. Cup orientation is navigated according to the stem anteversion. We have reported the same level of accuracy for cup navigation in revision THA as that of primary THA using cementless cups. We also applied cup navigation for cemented cups in this series. Thus we had no dislocation due to high precision in cup placement though we have no control. Our experience using CT-based navigation in revision THA suggests that computer navigation can reduce the risk of dislocation and improves longevity in revision THA.

#5796

The Outcome of Revision Surgery for Failed Metal-on-Metal Total Hip Arthroplasty

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Aims: Metal-on-metal total hip replacements (MoM THRs) are frequently revised. However, there is a paucity of data on clinical outcomes following revision surgery in this cohort. We report on outcomes from the largest consecutive series of revisions from MoM THRs and consider pre-revision factors which were prognostic for functional outcome.

Materials and Methods: A single-centre consecutive series of revisions from MoM THRs performed during 2006-2015 was identified through a prospectively maintained, purpose-built joint registry. The cohort was subsequently divided by the presence or absence of symptoms prior to revision. The primary outcome was functional outcome (Oxford Hip Score (OHS)). Secondary outcomes were complication data, pre- and post-revision serum metal ions and modified Oxford classification of pre-revision magnetic resonance imaging (MRI). In addition, the study data along with demographic data was interrogated for prognostic factors informing on post-revision functional outcome.

Results: 180 revisions in 163 patients were identified at a median follow-up of 5.48 (2-11.7) years. There were 152 (84.4%) in the symptomatic subgroup and 28 (15.6%) in the asymptomatic group. Overall median OHS improved from 29 to 37 with revision ($P<0.001$). Symptomatic patients experienced greater functional benefit (DOHS 6.5 vs. 1.4, $p=0.012$) compared to asymptomatic patients, though they continued to report inferior outcomes (OHS 36.5 vs 43, $p=0.004$). The functional outcome of asymptomatic patients was unaffected by revision surgery (pre-revision OHS 41, post-revision OHS 43, $p=0.4$). Linear regression analysis confirmed use of a cobalt-chrome (CoCr)-containing bearing surface (MoM or metal-on-polyethylene) at revision and increasing BMI were predictive of poor functional outcome (R^2 0.032, $p=0.0224$ and R^2 0.039, $p=0.015$ respectively). Pre- and post-revision serum metal ions and pre-revision MRI findings were not predictive of outcome. The overall complication rate was 36% (n=65) with a re-revision rate of 6.7%. The most common complication was ongoing adverse reaction to metal debris (ARMD, defined as positive post-revision MRI) in 21.1%. The incidence of ongoing ARMD was not significantly different between those with CoCr reimplanted and those without ($p=0.12$).

Conclusions: To our knowledge, our study represents the largest single-centre consecutive series of revision THRs from MoM bearings in the literature. Symptomatic patients experience the greatest functional benefit from revision surgery but do not

regain the same level of function as patients who were asymptomatic prior to revision. The re-implantation of CoCr as a primary bearing surface and increasing BMI was associated with poorer functional outcome.

Evaluation of Pull-Off Strength and Seating Displacement of Revision Ceramic Heads and Taper Adapter Sleeves in Modular Hip Arthroplasty

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INTRODUCTION:
Ceramic heads are used in hip revision surgery to mitigate corrosion concerns. Manufacturers recommend using a pristine titanium sleeve in conjunction with a well-fixed metal stem to prevent early failure of the ceramic head. However, the influence of impact force, head size, and sleeve offset on pull-off strength and seating displacement of a revision head assembly is not fully understood. Therefore, the purpose of this study was to investigate the pull-off strength and displacement of commercially available revision ceramic heads and titanium taper sleeve offsets (BIOLOX OPTION, CeramTec GmbH, Plochingen, Germany) while covering a range of clinically relevant impaction forces.

METHODS:
Two head sizes (28 mm, n = 12 and 36 mm, n = 12) and two taper adapter sleeve offsets (small, n = 12 and extra-large, n = 12) were tested in this study (Fig. 1). A dynamic impaction rig was constructed to seat the head, sleeve, and stem assembly (Fig. 1). Consistent impaction forces were achieved by a dropping a hammer fixed to a lever arm from a pre-determined height onto a standard impactor instrumented with a piezoelectric force sensor (PCB Piezotronics Inc.). Axially applied forces of 2 kN and 6 kN were used to cover a range of typical impaction forces. Three non-contact differential variable reluctance transducers (LORD Sensing Systems) were used to track the displacement of the head relative to the stem. Subsequently, samples were transferred a servo hydraulic testing machine, and a pull-off test was carried out per ISO 7206-10 to measure the disassembly force.

RESULTS:
For all head and sleeve combinations assembled at 6 kN, pull-off forces and assembly displacements were over two times the values measured at 2 kN. As expected, an increased assembly force resulted in increased pull-offs and displacements (Fig 2, 3). Head size did not play a significant role on measured outcomes. Regarding sleeve offsets, at assembly of 6 kN mean pull-off forces for extra-large sleeves were reduced by approximately 25% relative to small sleeves (Fig 2). However, at a 2 kN assembly, sleeve offsets did not appear to influence pull-off forces.

DISCUSSION:
This study assessed the effect of impact assembly force, head size, and sleeve offset on pull-off strength and seating displacement of revision ceramic heads. The data suggests assembly force and sleeve offset may influence the pull-off strength and seating displacement of modular heads used in revision hip arthroplasty. Mean pull-off forces for revision heads were comparable in magnitude and trend to previous studies assessing the linear relationship between assembly force and pull-off force in primary heads (Krull et al., 2017, Rehmer et al., 2012). Lower pull-off forces were observed for extra-large sleeves when compared to small sleeves, indicating, decreased contact at the sleeve and stem interface for extra-large offsets may play a role in reducing pull-off forces.

ACKNOWLEDGEMENT:

The authors would like to thank CeramTec GmbH (Plochingen, Germany) for providing the head, sleeve, and stem implants.

Figures

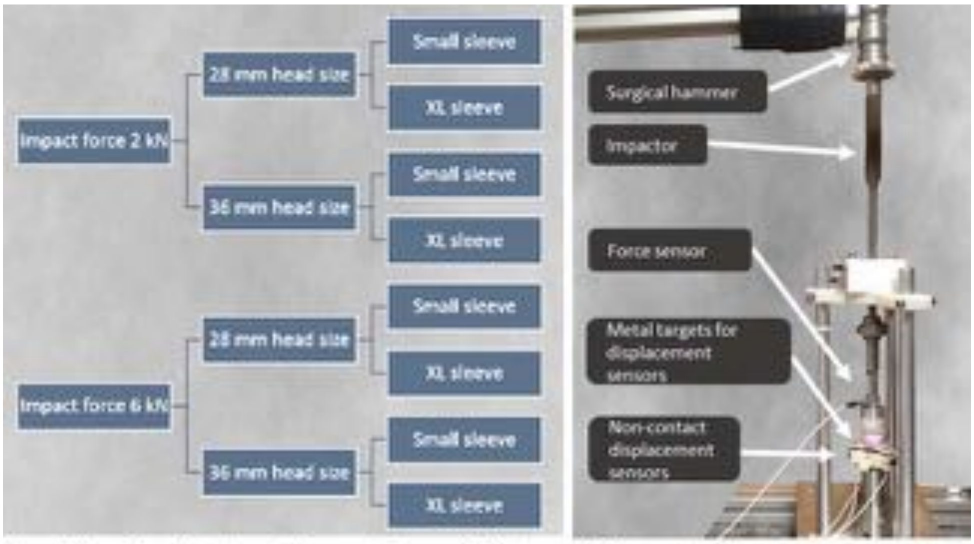

Fig. 1. Tested combinations of impaction force, head size, and sleeve size. Dynamic impaction rig constructed for this study.

Figure 1

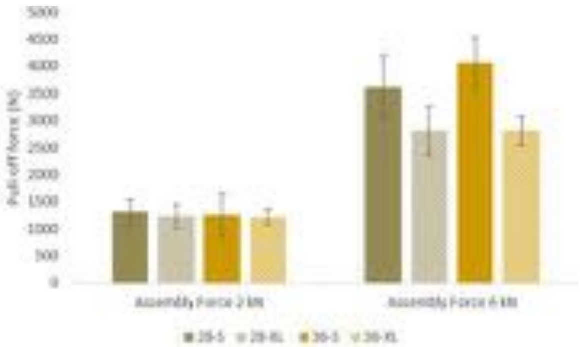

Fig. 2. Measured pull-off forces for all combinations of assembly force, head size and sleeve size.

Figure 2

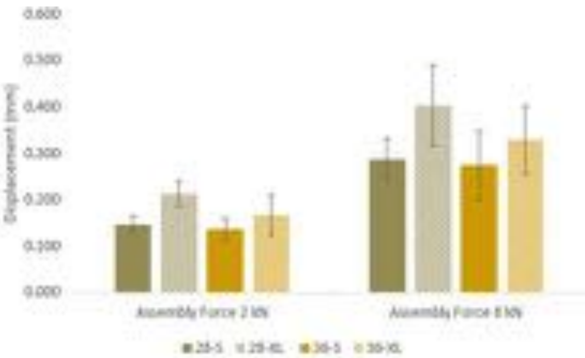

Fig. 3. Measured assembly displacements for all combinations of assembly force, head size and sleeve size.

Figure 3

#5710

Computer Navigation for Revision Total Hip Arthroplasty Reduces Dislocation Rates

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Introduction: Computer-assisted hip navigation offers the potential for more accurate placement of hip components, which is important in avoiding dislocation, impingement, and edge-loading. The purpose of this study was to determine if the use of computer-assisted hip navigation reduced the rate of dislocation in patients undergoing revision THA.

Methods and Materials: We retrospectively reviewed 72 patients who underwent computer-navigated revision THA [Fig. 1] between January 2015 and December 2016. Demographic variables, indication for revision, type of procedure, and postoperative complications were collected for all patients. Clinical follow-up was performed at 3 months, 1 year, and 2 years. Dislocations were defined as any episode that required closed or open reduction or a revision arthroplasty. Data are presented as percentages and was analyzed using appropriate comparative statistical tests (z-tests and independent samples t-tests).

Results: All 72 patients (48% female; 52% male) were included in the final analysis [Fig. 2]. Mean age of patients undergoing revision THA was 70.4 ± 11.2 years. Mean BMI was 26.4 ± 5.2 kg/m^2. The most common indications for revision THA were instability (31%), aseptic loosening (29%), osteolysis/eccentric wear (18%), infection (11%), and miscellaneous (11%). During revision procedure, polyethylene component was most commonly changed (46%), followed by femoral head (39%), and acetabular component (15%). At 3 months, 1 year, and final follow-up, there were no dislocations among all study patients (0%). Compared to preoperative dislocation values, there was a significant reduction in the rate of dislocation with the use of computer-assisted hip navigation (31% vs. 0%; $p<0.05$).

Discussion: Our study demonstrates a significant reduction in the rate of dislocation following revision THA with the use of computer navigation. Although the cause of postoperative dislocation is often multifactorial, the use of computer-assisted surgery may help to curtail femoral and acetabular malalignment in revision THA.

Figures

Figure 1. The Intellijoint HIP® mini-navigation system. The camera (A) sits atop a pelvic platform (B), fixed to the iliac crest via two surgical pins. The camera tracks movement of the tracker (C), which can be magnetically attached to a platform fixed to the greater trochanter (as illustrated) or to other objects during surgery (e.g. impactor, surgical probe). Intraoperative data is relayed from the camera and captured on a computer workstation that remains outside of the sterile field but within view of the surgical team.

Figure 1

Demographic summary.

Variable	Result, n/N (%)
Gender	
Male	37/72 (52%)
Female	35/72 (48%)
Body mass index (BMI)	26.4 ± 5.2 kg/m^2
Indications for revision	
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Aseptic loosening	21/71 (29%)
Osteolysis/eccentric wear	13/72 (18%)
Infection	8/72 (11%)
Miscellaneous	8/72 (11%)
Components changed	
Polyethylene	33/72 (46%)
Femoral head	28/72 (39%)
Acetabular component	11/72 (15%)
Dislocations	0/72 (0%)

Figure 2

Trabecular Titanium Tailored Implants in Complex Acetabular Revision Surgeries

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BACKGROUND: Total hip revision surgery in cases with previous multiple reconstructive procedures is a challenging treatment due to difficulties in treatment huge bone defects with standard revision prosthetic combinations. A new specially made production system in Electron-Beam Melting (EBM) technology based on a precise analysis of patients' preoperative CT scans has been developed.

METHODS: Objectives of design customizationin difficult cases are tocorrectlyevaluate patient's anatomy, to plan a surgical procedure and to obtain an optimal fixation to a poor bone stock. The 3D Printing (EBM) technology permits to create an extremely flexible patient matching implant and instrument, with material performances not viable with standard manufacturing process. Dedicated visual 3D tools and instrumentations improve implants congruency according to preoperative plan. Primary stability is enhanced and tailored on patient's anatomy by means of press-fit, iliac stems and the high friction performances of Trabecular Titanium matrix. The use of bone screws and their position is designed to enhance primary stability, even in critical bone conditions, avoiding implant stress shielding and allowing bone integration. 4 cases (2 men and 2 women) of acetabular customized implants were performed. Mean age at surgery was 51.5 years (range 25-72). Patients were reviewed clinically and radiographically at follow-up.

RESULTS: No signs of miss-match between intraoperative bone conditions and pre-operative planning were observed. No additional bone grafts or further native bone removal were needed. Biomechanical parameters were restored by using internal modularity (i.e. face-changers / angled spacers). Face-changers allow to correct coverage and anteversion of the acetabular system. Incompatibility or impingement between the stems and new acetabular component was not observed and stem revision was performed in one case. On-table stability proved excellent and no intraoperative complications were observed. All patients underwent an immediate mobilization with full weight-bearing. Mean Harris Hip Score increased significantly from 13.9 (range 6.9-20.6) preoperatively to 75.8 (range 53.9-94) at last follow-up (mean 17.5, range: 10-33), showing an improvement in terms of both pain relief, function and joint mobility. Radiographically neither signs of instability, migration nor tilting were observed [Fig.1-2]. No case of dislocation nor infection were recorded.

CONCLUSION:A detailed anatomical reconstruction, in-depth preoperative planning, custom-implant design, high performance of the 3D-printing technology, system modularity and patient-specific surgical tools permitted an effective restoration of the biomechanical joint parameters in these complex revision cases. The optimal primary stability of the implants promoted an early osseointegration with the remaining bone stock. Further studies shall be necessary to assess the performance of these Implants at long-term follow-up.

Figures

Figure 1

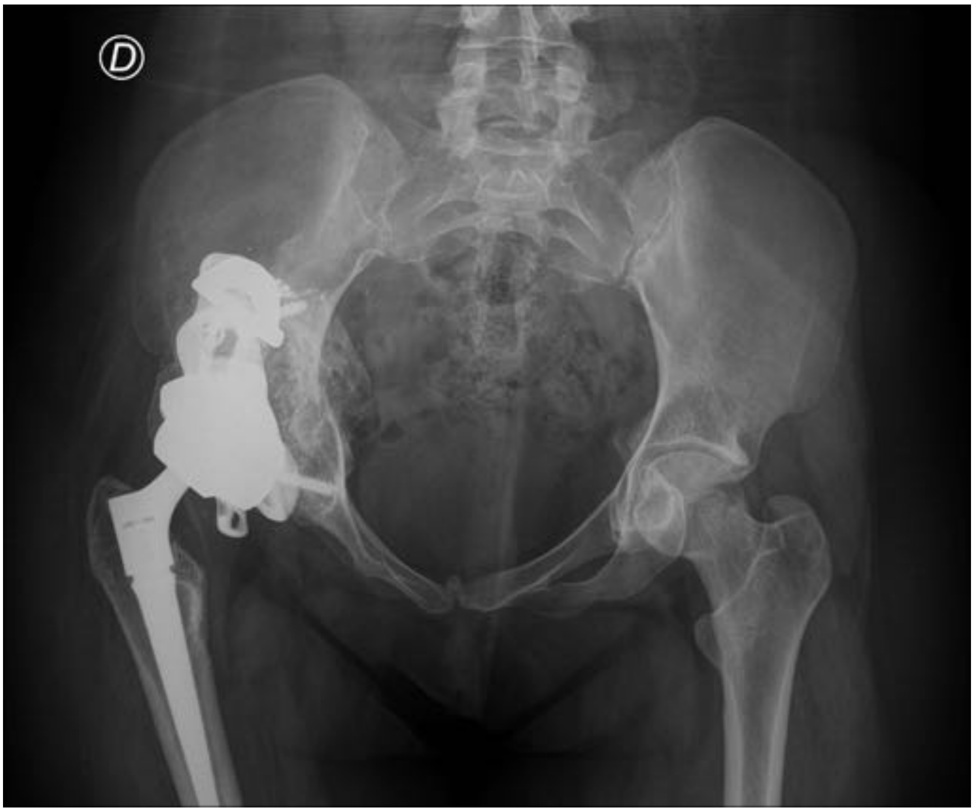

Figure 2

Pseudotumor Recurrence in a Post-Revision Total Hip Arthroplasty With Stem Neck Modularity

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*George Chimento - Ochsner Health System - New Orleans, USA
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Total hip arthroplasty (THA) is one of the most successful surgeries in all of medicine. Advancements in technology have allowed prosthesis design to accommodate patient factors, level of activity, and surgical approaches. One specific variation on prosthesis design includes modular neck systems. The modular neck system aims to reproduce the natural biomechanics of the hip by adding junctions that allow individual adjustments to prosthetic components. However, many of these systems have been recalled in recent years due to high revision rates resulting from metal debris deposition at the modular junctions. Such depositions have been shown to induce a host hypersensitivity reaction leading to aseptic lymphocytic vasculitis-associated lesions (ALVALs). The formation of these pseudotumors is well-established as an adverse outcome in total hip arthroplasty prostheses involving metal-on-metal (MoM) implants and although less commonly, with modular stem neck systems as well. Surgical debridement and revision THA have led to complete resolution of symptoms in the majority of cases – exceptions were limited exclusively to pseudotumor recurrence in MoM THA. Post-revision pseudotumor recurrence in femoral stems with neck modularity has been previously reported only once based on the literature review conducted for this article – again associated with an initial MoM implant. The authors of this case report present a 74-year-old man with left recurrent ALVALs status post-revision THA.

The initial THA was completed in the context of long-standing degenerative osteoarthritis using a modular stem-neck prosthesis involving a ceramic head and bi-modular neck (Figure 1). The patient had no immediate post-operative complications and progressed to significantly improved mobility of his left lower extremity. Five years later, the patient presented with a left thigh swelling and was diagnosed with pseudotumor based on CT-guided fine needle aspiration, MRI findings, and elevated serum metal ion levels (serum cobalt = 12 ng/mL; serum chromium = 2.8 ng/mL) (Figure 2). The pseudotumor was subsequently treated with debridement and left revision THA. The revision THA was completed by extracting the femoral stem and replacing it with a distally tapered modular stem and a ceramic femoral head. At two-week follow-up, the patient was ambulating well with a cane and had no acute post-operative complications. Four months later, the patient presented with a two-week history of a recurrent left thigh swelling. New pseudotumor formation in a location similar to the initial lesion was noted on MRI although with significantly lower serum metal ions compared to initial presentation (serum cobalt = 1.5 ng/mL; serum chromium = 1.4 ng/mL) (Figure 3). Fine needle aspiration of the lesion yielded 15cc of clotted blood, resembling the aspiration findings of the initial lesion. This is the first reported case of post-revision pseudotumor recurrence in a THA with stem neck modularity not utilizing MoM implants.

The recurrence of these lesions in a patient whose implants have not been previously associated with this adverse outcome begs further questioning. Raising awareness of this adverse outcome in post-revision THA can guide clinicians to early identification and treatment for patients with post-operative thigh swelling.

Figures

Figure 1

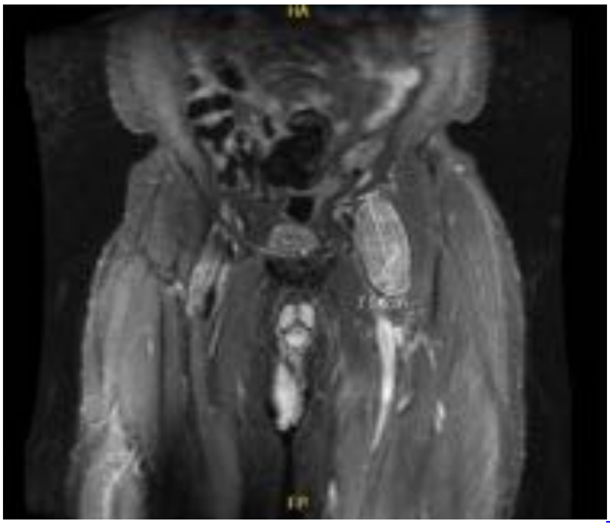

Figure 2

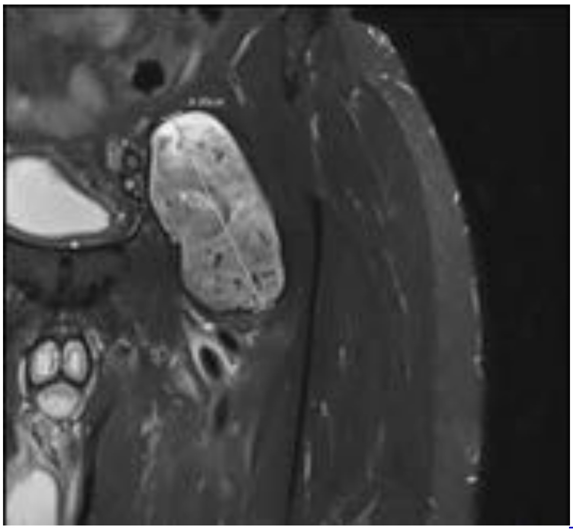

Figure 3

#5796

The Outcome of Revision Surgery for Failed Metal-on-Metal Total Hip Arthroplasty

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Aadil Mumith - Basingstoke and North Hampshire Hospital - Basingstoke, United Kingdom
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Toby Briant-Evans - Basingstoke and North Hants Hospital - Basingstoke, United Kingdom
Geoff Stranks - Basingstoke and North Hants Hospital - Basingstoke, United Kingdom
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Aims: Metal-on-metal total hip replacements (MoM THRs) are frequently revised. However, there is a paucity of data on clinical outcomes following revision surgery in this cohort. We report on outcomes from the largest consecutive series of revisions from MoM THRs and consider pre-revision factors which were prognostic for functional outcome.

Materials and Methods: A single-centre consecutive series of revisions from MoM THRs performed during 2006-2015 was identified through a prospectively maintained, purpose-built joint registry. The cohort was subsequently divided by the presence or absence of symptoms prior to revision. The primary outcome was functional outcome (Oxford Hip Score (OHS)). Secondary outcomes were complication data, pre- and post-revision serum metal ions and modified Oxford classification of pre-revision magnetic resonance imaging (MRI). In addition, the study data along with demographic data was interrogated for prognostic factors informing on post-revision functional outcome.

Results: 180 revisions in 163 patients were identified at a median follow-up of 5.48 (2-11.7) years. There were 152 (84.4%) in the symptomatic subgroup and 28 (15.6%) in the asymptomatic group. Overall median OHS improved from 29 to 37 with revision ($P<0.001$). Symptomatic patients experienced greater functional benefit (DOHS 6.5 vs. 1.4, $p=0.012$) compared to asymptomatic patients, though they continued to report inferior outcomes (OHS 36.5 vs 43, $p=0.004$). The functional outcome of asymptomatic patients was unaffected by revision surgery (pre-revision OHS 41, post-revision OHS 43, $p=0.4$). Linear regression analysis confirmed use of a cobalt-chrome (CoCr)-containing bearing surface (MoM or metal-on-polyethylene) at revision and increasing BMI were predictive of poor functional outcome (R^2 0.032, $p=0.0224$ and R^2 0.039, $p=0.015$ respectively). Pre- and post-revision serum metal ions and pre-revision MRI findings were not predictive of outcome. The overall complication rate was 36% (n=65) with a re-revision rate of 6.7%. The most common complication was ongoing adverse reaction to metal debris (ARMD, defined as positive post-revision MRI) in 21.1%. The incidence of ongoing ARMD was not significantly different between those with CoCr reimplanted and those without ($p=0.12$).

Conclusions: To our knowledge, our study represents the largest single-centre consecutive series of revision THRs from MoM bearings in the literature. Symptomatic patients experience the greatest functional benefit from revision surgery but do not

regain the same level of function as patients who were asymptomatic prior to revision. The re-implantation of CoCr as a primary bearing surface and increasing BMI was associated with poorer functional outcome.

#6035

Evaluation of Pull-Off Strength and Seating Displacement of Revision Ceramic Heads and Taper Adapter Sleeves in Modular Hip Arthroplasty

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INTRODUCTION:
Ceramic heads are used in hip revision surgery to mitigate corrosion concerns. Manufacturers recommend using a pristine titanium sleeve in conjunction with a well-fixed metal stem to prevent early failure of the ceramic head. However, the influence of impact force, head size, and sleeve offset on pull-off strength and seating displacement of a revision head assembly is not fully understood. Therefore, the purpose of this study was to investigate the pull-off strength and displacement of commercially available revision ceramic heads and titanium taper sleeve offsets (BIOLOX OPTION, CeramTec GmbH, Plochingen, Germany) while covering a range of clinically relevant impaction forces.

METHODS:
Two head sizes (28 mm, n = 12 and 36 mm, n = 12) and two taper adapter sleeve offsets (small, n = 12 and extra-large, n = 12) were tested in this study (Fig. 1). A dynamic impaction rig was constructed to seat the head, sleeve, and stem assembly (Fig. 1). Consistent impaction forces were achieved by a dropping a hammer fixed to a lever arm from a pre-determined height onto a standard impactor instrumented with a piezoelectric force sensor (PCB Piezotronics Inc.). Axially applied forces of 2 kN and 6 kN were used to cover a range of typical impaction forces. Three non-contact differential variable reluctance transducers (LORD Sensing Systems) were used to track the displacement of the head relative to the stem. Subsequently, samples were transferred a servo hydraulic testing machine, and a pull-off test was carried out per ISO 7206-10 to measure the disassembly force.

RESULTS:
For all head and sleeve combinations assembled at 6 kN, pull-off forces and assembly displacements were over two times the values measured at 2 kN. As expected, an increased assembly force resulted in increased pull-offs and displacements (Fig 2, 3). Head size did not play a significant role on measured outcomes. Regarding sleeve offsets, at assembly of 6 kN mean pull-off forces for extra-large sleeves were reduced by approximately 25% relative to small sleeves (Fig 2). However, at a 2 kN assembly, sleeve offsets did not appear to influence pull-off forces.

DISCUSSION:
This study assessed the effect of impact assembly force, head size, and sleeve offset on pull-off strength and seating displacement of revision ceramic heads. The data suggests assembly force and sleeve offset may influence the pull-off strength and seating displacement of modular heads used in revision hip arthroplasty. Mean pull-off forces for revision heads were comparable in magnitude and trend to previous studies assessing the linear relationship between assembly force and pull-off force in primary heads (Krull et al., 2017, Rehmer et al., 2012). Lower pull-off forces were observed for extra-large sleeves when compared to small sleeves, indicating, decreased contact at the sleeve and stem interface for extra-large offsets may play a role in reducing pull-off forces.

ACKNOWLEDGEMENT:

The authors would like to thank CeramTec GmbH (Plochingen, Germany) for providing the head, sleeve, and stem implants.

Figures

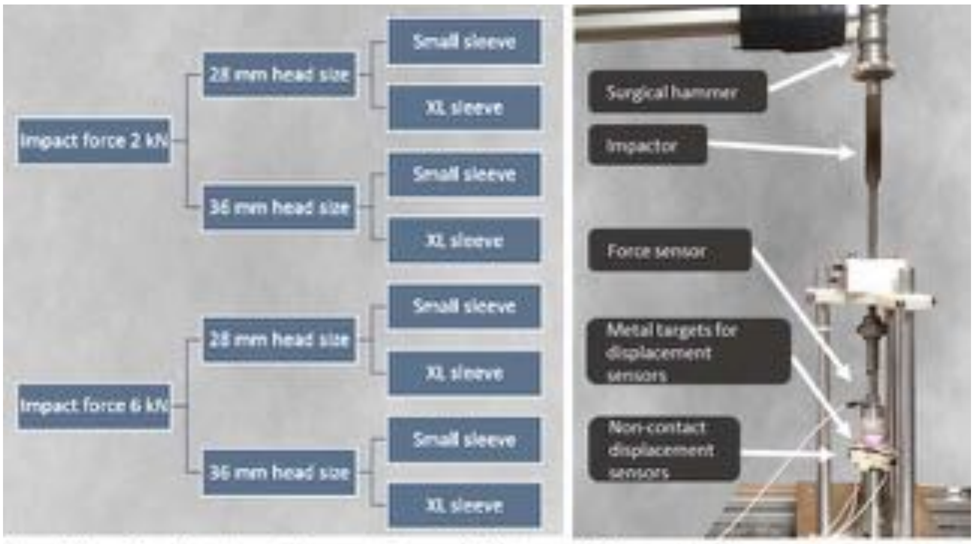

Fig. 1. Tested combinations of impaction force, head size, and sleeve size. Dynamic impaction rig constructed for this study.

Figure 1

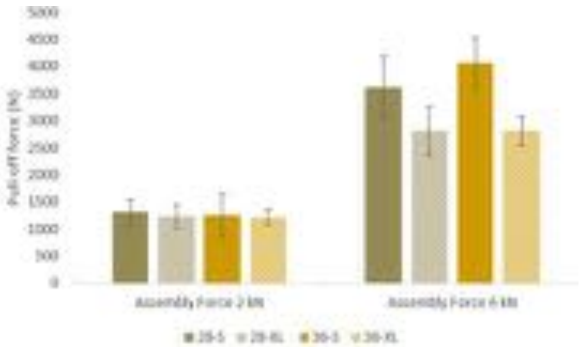

Fig. 2. Measured pull-off forces for all combinations of assembly force, head size and sleeve size.

Figure 2

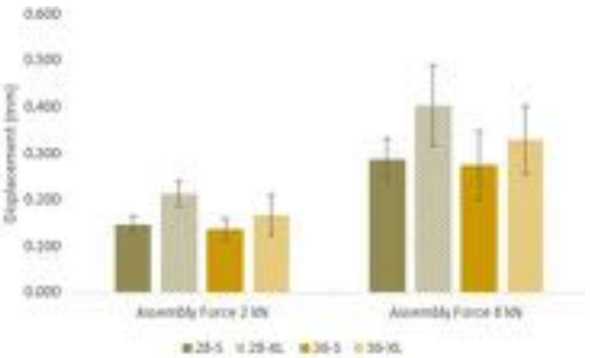

Fig. 3. Measured assembly displacements for all combinations of assembly force, head size and sleeve size.

Figure 3

#5710

Computer Navigation for Revision Total Hip Arthroplasty Reduces Dislocation Rates

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#5666

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Figures

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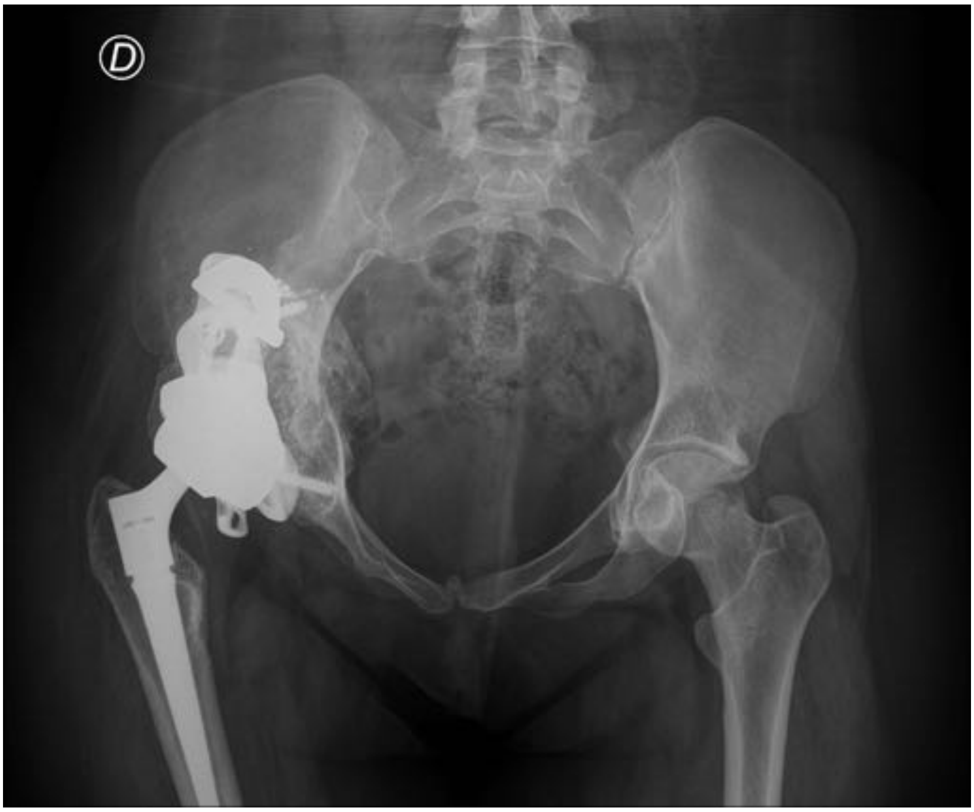

Figure 2

#5781

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Bhumit Desai - The University of Queensland - Ochsner Clinical School - New Orleans, USA
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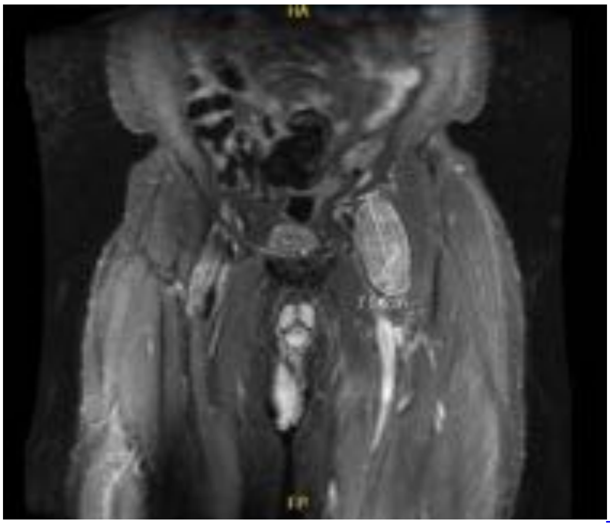

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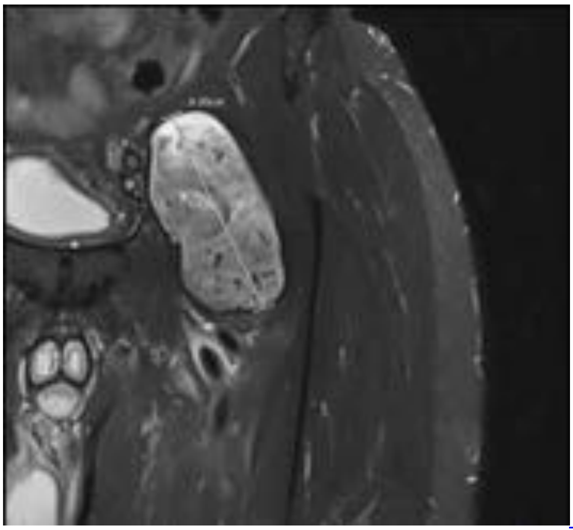

Figure 3

#5821

Novel Cervical Interbody Spacer to Detect Fusion Radiographically

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Introduction: Pseudarthrosis of the cervical spine is the result of failed attempted fusion and is a leading cause of postoperative axial pain and radiculopathy.[1] Reported rates of failed cervical fusion range from 4.4 to 50% and pseudarthrosis accounts for 45 – 56% of revision surgeries.[1] Nonunion is difficult to detect clinically with identification based solely on symptomatology (neck pain, radiculopathy) and imaging.[1] The gold standard approach to define fusion status involves surgical exploration, a last resort option.[2] Radiographic tools are commonly used first, with computed tomography (CT) considered the most reliable.[2] Because CT scans are expensive, time consuming, and expose patients to large radiation doses, they are only ordered given a high index of suspicion. Fusion status can also be deduced from plain radiographs by measuring and comparing the distance between tips of adjacent spinous processes on lateral flexion and extension films, a process termed "interspinous motion analysis".[3] However, the technique is subjective and affected by parallax, and studies have found wide inter-observer differences.[4] Therefore quantitative and standardized methods for defining spinal fusion or instability are needed.We have invented and reduced to practice a cervical spine spacer that can detect intervertebral motion, and responds to the pressure differential within the disc space between the flexed and extended positions. This can be visualized using standard radiography.

Methods: A cervical interbody spacer with integrated fluidic pressure sensor was developed, incorporating a fluid reservoir and indicator capillary. The spacer was placed between Sawbones® vertebra analogs in simulated dynamic spinal positions. A single-column compression tester was used to apply loads comparable to those experienced by vertebra in the cervical region (~60 – 100N).[5] Radiographs were taken of a device loaded with radiocontrast (cesium acetate) and channel diameter of 0.5mm.

Results: Computer simulations and prototypes placed between cervical bone analogs demonstrated that the signal would be apparent clinically (Figure 1A&B). Previous work showed that fluid displacement into the indicator portion was in the appropriate scale (0 – 6.9 mm) under applied loads in the clinical range (0 – 110 N);[5] this relationship was linear and repeatable (Figure 1D). The imaging resolution of the device was also within the clinical range, and apparent on radiographs (Figure 1C).

Conclusions: An interbody device with fluidic sensor is potentially a viable option for assessing fusion status in the cervical spine. This concept offers two primary advantages over existing techniques. First, the indicator provides a clear and distinct signal that can be plainly read on radiographs, simplifying comparisons between flexed, neutral and extended positions and enabling monitoring over time. Second, the device introduces gain proportional to the ratio of the cross-sectional areas of the reservoir and capillary, providing amplification and enabling detection of smaller changes. This device has been filed for IP protection[6] with Clemson University, who is the assignee.

Reference: 1. Raizman et al., JAmAcadOrthopSurg 2009. 2. Buchowski et al., Spine 2008. 3. Song et al., JBJSAm. 2014. 4. Taylor et al. Spine 2007. 5. Brodke et al.,

JBJSAm 2006. 6. Anker et al. USPTO WO2017027782A1

Figures

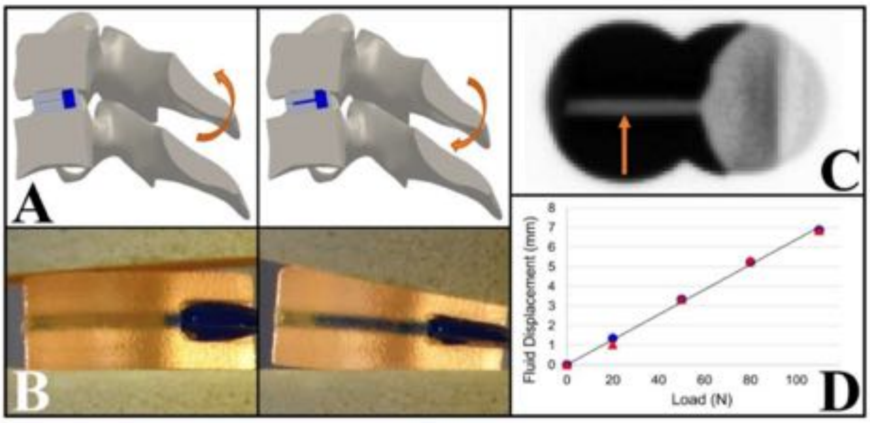

Figure 1: 3D CAD representations of device implanted **(A)** and Sawbones® vertebra analogs simulating flexed (left) and extended cervical spinal positions **(B)**. X-ray image of device with radiocontrast agent **(C)** and graph characterizing fluid displacment vs. load **(D)**.

Figure 1

#5637

Measurement of Intraoperative Range of Motion of Total Hip Arthroplasty Using an Inertial Measurement Unit Based Smart Tiral System: an in Vitro Validation Experiment

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Abstract

Introduction

Intraoperative detection of hip Range of Motion (ROM) is the basis for prediction of postoperative functional limits allowed for patients' daily living. Although computer navigation system for Total Hip Arthroplasty (THA) has improved the accuracy of intraoperative ROM evaluation, it has not been able to gain popularity because of its complex and time-consuming procedures.

Methods

We preliminarily developed a Inertial Measurement Unit based Hip Smart trial system (IMUHS) that is easy and simple to use. This system was composed of measurement hardware in a femoral head trial and application software in a terminal computer, which were connected via a USB cable. In the head trial, a 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer were applied to building an IMU system, Kalman filtering and 9-axis fusion algorithm were employed to computing the rotation angle on a microprogrammed control unit (MCU).An in vitro validation experiment was conducted using radiopaque sawbones with imaging measurement method based on mimics 14.0 software as the reference standard.

Results

The validity of measuring ROM in the three axes was as follows: 4.36±4.93°for flexion and extension, 1.75 ± 5.21°for adduction and abduction, and 6.42 ± 4.32°for internal and external rotation(p = 0.059 ~ 0.550). The ICC values of measuring ROM in all three axes were 1.00. As measuring ROM is the basis for evaluating direction of impingement, subluxation and dislocation, the IMUHS is a promising development direction of THA computer assisted surgery.

Conclusion

The IMUHS is a promising sensor system of THA computer assisted surgery.

Figures

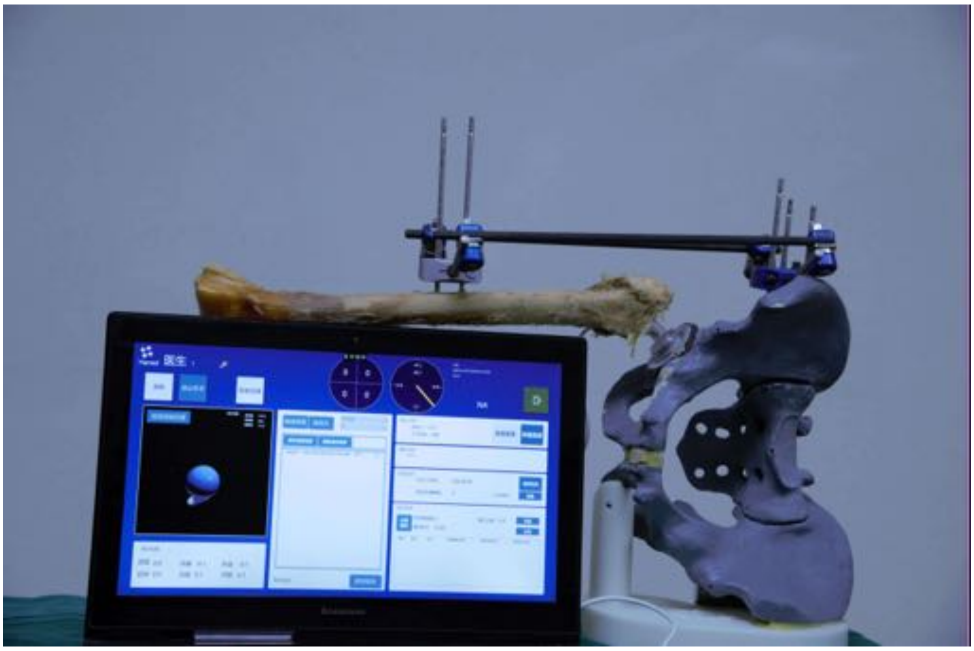
Figure 1

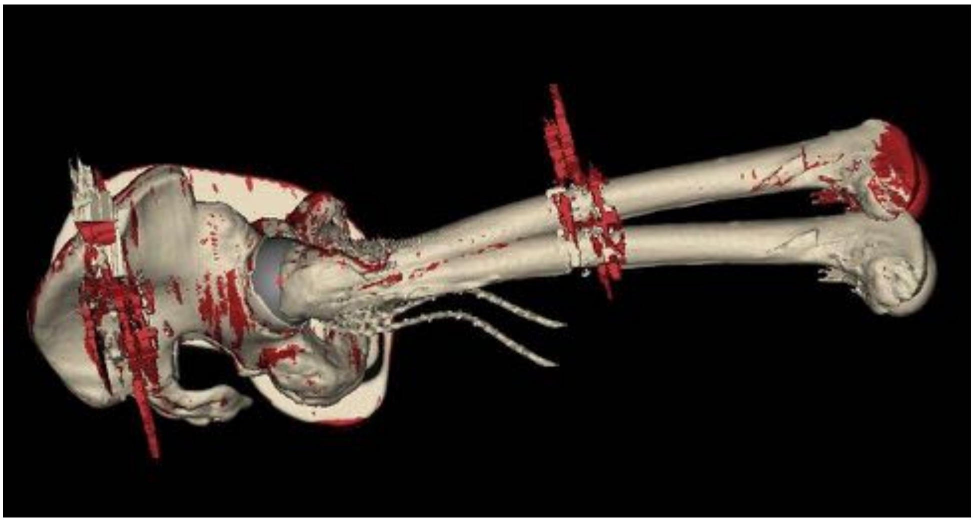
Figure 2

Presentation of the neckID concept – A personalized neck brace

Neck pain is one of the most prevalent and costly health problems in the United States [1]. Among US residents, 50–70% will experience neck pain at least once in their lives, with about 30% who are affected each year, and about 10% who suffer from neck pain at any given time [2]. Neck injury remains a complex, subjective experience with a variety of musculoskeletal causes. Studies have shown that neck injuries should be controlled and treated quickly to avoid further injury. Many approaches have been suggested to manage neck injury, including anti- inflammatory drugs, manipulation, supervised exercise, and neck braces.

Neck braces are expected to immobilize or reduce head and neck movement while allowing some type of range of motion for normal daily activities. However, the prescription of neck braces for the treatment of neck injury tends to be particularly arbitrary. Also, patient adherence to wearing a neck brace is greatly compromised by the discomfort associated which such device. Usually, conventional neck braces are available under a few basic size options to accommodate the entire population of patients to be treated. Finally, long periods of immobilization during the healing process may result in secondary effects such as atrophy- related secondary damage.

Based on conventional neck brace's lack of considerations for the patient's morphology (e.g., gender, ethnicity, stature) and pathology (e.g., level of immobilization), we decided to leverage modern technologies to develop the neckID, a patient-based neck brace (Fig. 1).

Our development is based on a 3D scan of the patient's neck as well as the guidance from a physician in terms of dimensional and immobilization requirements. From these data, the basic volume of the patient-based neck brace is designed using standard 3D CAD software. Then, a parametric element (e.g., hole or mesh) is assigned to the preliminary design and an iterative finite element analysis (FEA) type of simulation is performed using parametric optimization to modify the dimension of the structural elements to match the expected immobilization requirements. The last stage consists of 3D printing the neck brace using known additive manufacturing methods (Fig. 2). Assuming proper automation of the individual design tasks the full process is estimated to take less than 24 hours.

This patent pending approach encompasses three distinct personalization levels as an attempt to improve the treatment of the patients:

- Dimensional: Optimal fit with the patient's anatomy regardless of stature, gender, and ethnicity.

- Structural: Optimization of the mechanical properties to match the required immobilization levels to treat the pathology.

- Appearance: Selection of the material to match skin color and/or texture or any other color and/or texture based on patient's preferences. References:

1. Cherry DK, Burt CW, Woodwell DA. National Ambulatory Medical Care Survey: 1999 summary. Adv Data Vital Health Stat 2001;322

2. Bovim G, Schrader H, Sand T. Neck pain in the general population. Spine 1994;19:1307–9

Figure 1: Rendering of the neckID neck brace

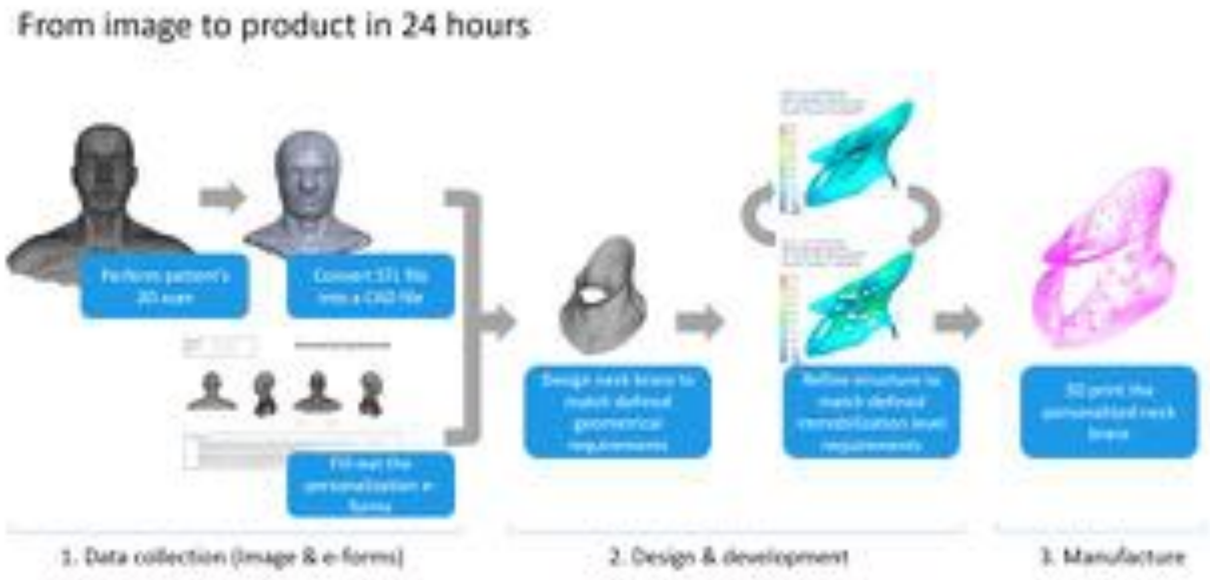

Figure 2: Overview of the design, development, and manufacturing process

A New Design of Tibial Baseplate in Bi-Cruciate Preservation TKR

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Purpose
Total knee replacement is the one of the most performed surgeries. However, patient's satisfaction rate is around 70-90 % only. The sacrifice of anterior cruciate ligament might be the main reason, especially in young and active patients. ACL stabilizes the knee by countering the anterior displacing and pivoting force, absorbs the shock and provides proprioception of the knee. Cruciate preservation knees has been plagued by injury of PCL during the bone cutting and removing of the cut bone. TKR designs which preserve both cruciate ligament have revived in recent years. However, preservation of the ACL is a demanding technique. The bone island where ACL footprint locates is weak, intraoperative fracture happened frequently. To insert a tibial baseplate with PE is usually bigger than 8 mm comparing to removed tibial bone. The stuffing of joint space may put undue tension on ACL and PCL complex. We developed a new design to solve the kinematic conflict and preserve the ACL and PCL function.
Method
A new tibial baseplate without the keel was designed. The central part of the baseplate has screw and suture holes for re-fixation of the elevated bony island with ACL footprint and fenestrations for bone regrowth. The elevation of bony island release the tension in the ACL which come from stuffing of baseplate and insert. The central connection between medial and lateral baseplate improve the mechanical strength of baseplate compares with the traditional U shape design of bi-cruciate knees.
Instead of keeping the bony island intact by separately cutting the medial and lateral tibial plateau (the two cut surfaces may not be in one plane) and trimming the bone island to fit the baseplate (the procedure and instruments are complex), we choose to cut the tibial plateau in one stroke as in traditional TKR. Then cut away the two condyles and preserve the bony island with footprint of ACL with jig. The central part of tibial baseplate during insertion will push the bony island upward which release the undue tension as mention above. In TKR with CR design, injury of PCL may need to convert to PS during surgery. Delayed rupture of PCL is also a documented complication of CR Knees. Preservation of the bony island could also prevent PCL from cutting during removal of tibial plateau bone plate.
Summary
We proposed a new solution for the kinematic conflict in the present bi-cruciate knee designs by elevation and re-fixation of bony island with ACL footprint at the same time simplify the ACL preservation. The single tibial cutting procedure could also facilitate the process. The protected PCL might save complications coming from its injury during tibial bone cutting.
We believe the new design has the potential to replace CR knee in term of function and longevity in the future.

Figures

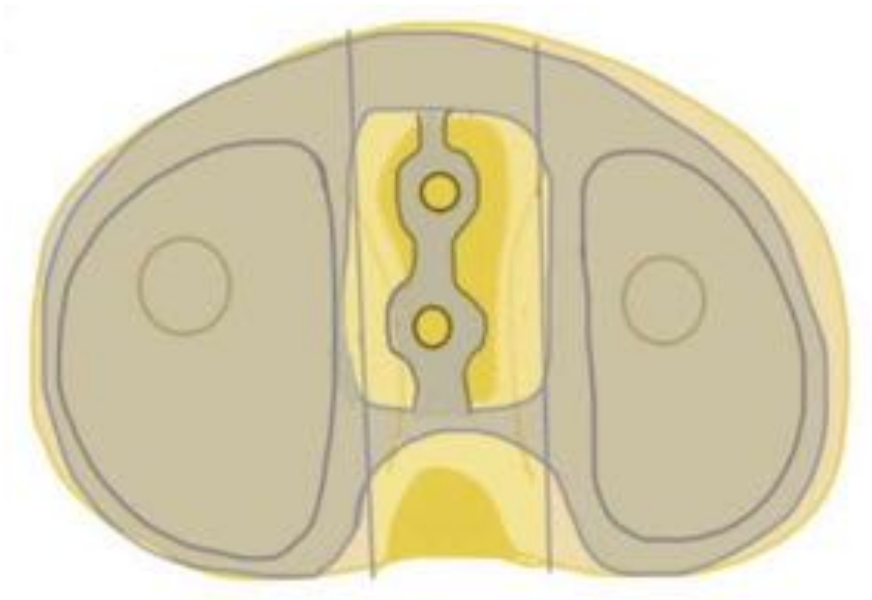

Figure 1

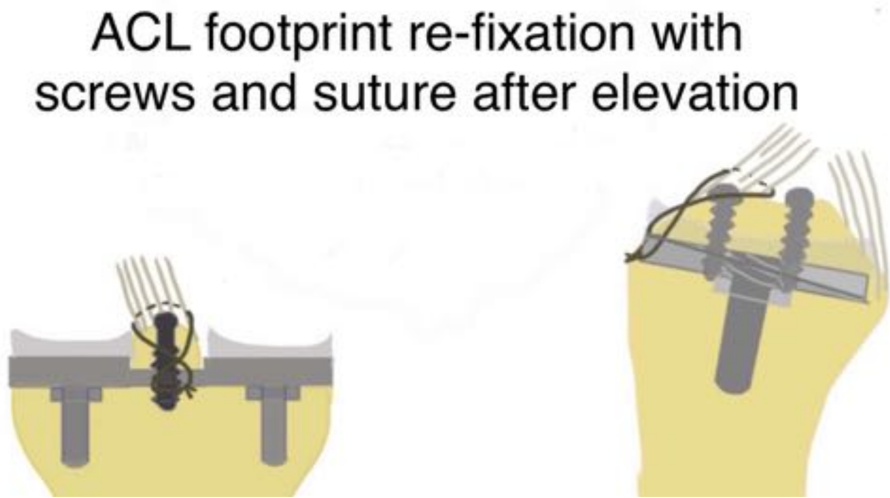

Figure 2

Novel automatic objective radiographic measurements for knee arthroplasty decision support

When rating radiographics, great inter-rater variability occurs, potentially affecting both research and patient outcomes. When diagnosis oateoarthritis (OA), rating the radiograph accurately is an important part of diagnosis, and pivotal when planning surgery from planar radiographs.
We propose an algorithm, that fully automatically can make objective measurements on knee radiographs, without any user input, using machine learning methods. The algorithm is trained on expert validated data, and the results is fast and reproducible, minimising variation between doctors. These results are objective and accurate measurements printed directly on the image, including joint-space width, varus/valgus rotation, osteophytes and deformation, and can effectively be used for the othopaedic surgeon to form decision on

- OA diagnosis and treatment
- if the patient is a candidate for unicompartmental knee replacement or total knee replacement
- best implant size and position in preoperative planning of arthroplasty

Radiobotics is an early stage startup based in Copenhagen, Denmark. We are working on automating measurements and descriptions on medical imaging, using the latest methodology of machine learning and deep learning, letting validated data drive the performance of our software. We are working closely with expert orthopaedic surgeons as well as expert radiologists, ensuring our products will be based on expert opinions.
With the millions of medical images being acquired every year related to arthroplasty, we see an opportunity in utilising the latest technological developments, aiding doctors by amplifying their ablities, making the patient outcome the best possible.

#6036

Are Patients More Satisfied With a Balanced TKA?

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Introduction & Aims – Studies have shown that as many as 1 in 5 patients is dissatisfied following total knee replacement (TKA). There has also been a large reported disparity between surgeon and patient perception of clinical “success”. It has long been shown that surgeon opinion of procedural outcomes is inflated when compared with patient-reported outcomes. Additionally, TKA recipients have consistently reported higher pain levels, greater inhibition of function, and lower satisfaction than total hip replacement (THA) recipients. It is imperative that alternative methods be explored to improve TKA patient satisfaction. Therefore, the purpose of this study was to determine whether or not patients with a balanced TKA, as measured using intraoperative sensors, exhibit better clinical outcomes.

Methods – 310 patients scheduled for TKA surgery were enrolled in a 6 center, randomized controlled trial, resulting in two patient groups: a sensor-guided TKA group and a surgeon-guided TKA group. Intraoperative load sensors were utilized in all cases, however in one group the surgeon used the feedback to assist in balancing the knee and in the other group the surgeon balanced without load data and the sensor was used to blindly record the joint balance. For this evaluation, the two groups were pooled and categorized as either balanced or unbalanced, as defined by a mediolateral load differential less than 15 lbf (previously described in literature). Clinical outcomes data were collected at 6 weeks, 6 months and 1 year post-operatively, including Knee Society Satisfaction and the Forgotten Joint Score. Using linear mixed models, these outcome measures were compared between the balanced and unbalanced patient groups.

Results – Of the 310 patients, 200 were balanced and 110 were unbalanced. When correcting for pre-operative expectations, adverse events, BMI, gender and age, patients with a balanced knee exhibited greater satisfaction at 6 weeks, 6 months and 1 year ($p=0.009$) compared to the patients with an unbalanced knee. Similarly, the same balanced cohort of patients with a balanced knee showed a more forgotten joint (higher Forgotten Joint Score) at the same tine intervals.

Conclusions – As patient reported outcomes become increasingly important for maintaining favorable hospital and provider metrics, it is imperative to find new methods to increase satisfaction levels among TKA recipients. In this study, patients with quantitatively balanced TKA had significantly better KSS satisfaction and forgotten joint scores compared to patients with unbalanced TKA. Longer-term follow-up is ongoing to determine whether these differences are sustained at two years post-surgery.

#5784

Can We Predict Laxity in Robotic TKA Using Pre-Operative Force-Controlled Laxity Measurements?

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Introduction: Soft tissue balance is critical to good outcomes in TKA. However, manual balancing methods commonly rely on subjective surgeon feel and experience and have been shown to produce variable results [1]. The purpose of this study was to therefore assess the accuracy and repeatability of a new TKA technique that uses robotically-controlled ligament tensioning and integrated 3D implant planning to achieve a targeted degree of soft-tissue balance.

Methods: Sixty consecutive robotic TKA patients (mean age 72±11, BMI 27.3±8.3) were included in this study. After resecting the proximal tibia, a robotic ligament tensioning device (OMNIBotics® Active Spacer, OMNI, Raynham, MA) was inserted into the knee and used to independently apply 80-100N of tension to the medial and lateral compartments (fig 1a). With the Active Spacer in the knee joint, a pre-operative gap profile was acquired throughout flexion as the limb was manually taken through a range of motion. The femoral implant was then planned to have a mediolateral balance within 1mm in extension and flexion, and a virtual gap algorithm displayed the predicted post-operative TKA gap profiles throughout the range of motion (fig 1b). A robotic cutting-guide was used to perform the femoral resections and a femoral trial component was inserted. The Active Spacer was then reinserted into the joint in place of the tibial insert, and the post-operative gap profile was acquired using the same loading profile as for the pre-operative gap acquisition. The predicted and post-operative gap profiles were respectively calculated and measured as the distance from the tibial resection to the closest point on the femoral implant. The mean and standard deviation of the medial and lateral prediction error were calculated for all knees. Paired t-tests were used to identify significant differences between the predicted and measured post-operative gaps across the flexion arc. The distribution of post-operative knee balance at 0, 10, 30, and 90 degrees of flexion was calculated in 1mm increments.

Results: Average discrepancy between the predicted and post-operative gaps was 0.4±1.1mm and 0.3±0.8mm for the medial and lateral gaps respectively (Fig 2). The maximum error was 2.7mm and 1.8mm while the RMS error was 1.3mm and 1.6 mm for the medial and lateral side respectively. Differences between the predicted and the measured post-op gaps for both sides were not statistically significant for all flexion angles ($p>0.8$).

The percentage of knees balanced to within 2mm mediolaterally ranged from 88-96% depending on the flexion angle (fig 3). Maximum imbalance was less than 3mm across all knees and flexion angles.

Discussion: Knee balance could be accurately predicted and achieved to within 2mm using active ligament tensioning. This represents an improvement in accuracy when compared with manual instrumentation [1]. Some of the variation between the predicted and actual post-op gaps is likely due to small variations in the planned vs actual bone resections, in the soft-tissue properties during the procedure, and in the pre- vs post-operative knee gap kinematic acquisitions.

References: [1] Joseph J et al. The Knee 20 (2013) 401-6.

Figures

Fig 1 a) Intra-operative photo showing the Active Spacer inserted in the knee, Fig 1 b) Femoral implant planning software with predictive gaps throughout the range of flexion (left)

Figure 1

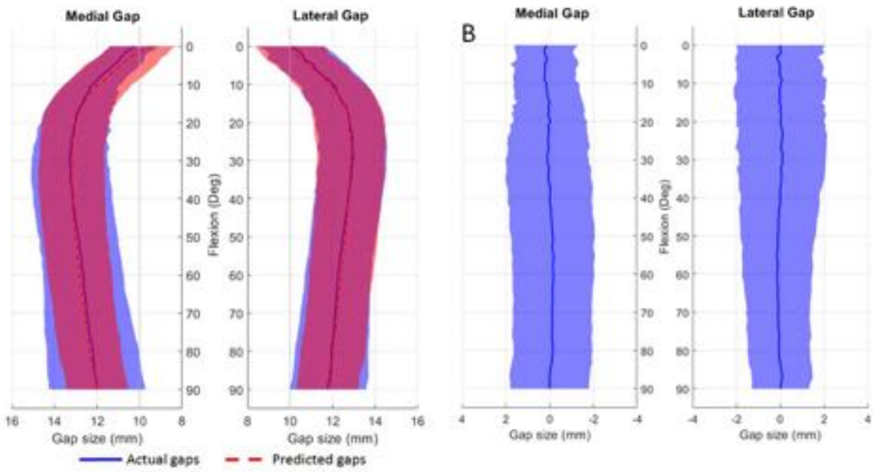

Fig 2 a) Medial and lateral gap profiles for the predicted post-operative gap (blue) and actual measured post-operative gap (red); b) the error between the predicted and post-operative gaps. Shaded areas represent +/- one standard deviation.

Figure 2

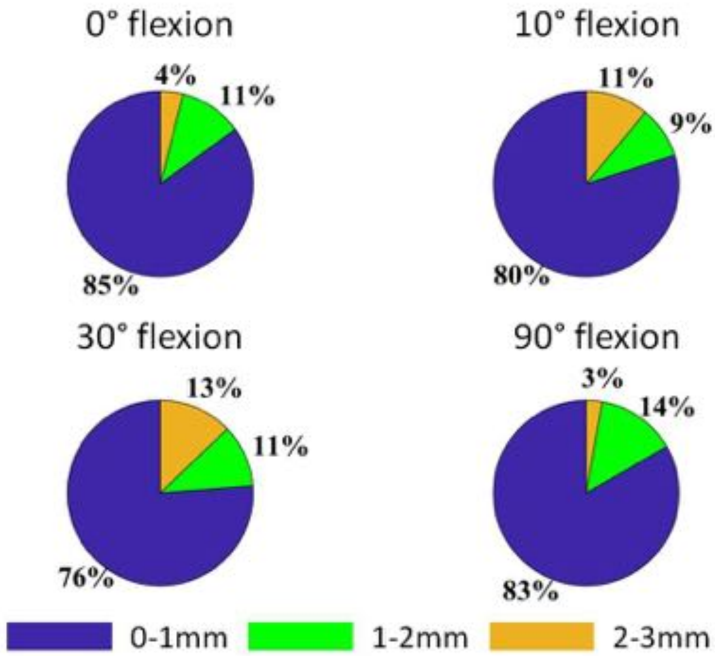

Fig 3 – Distribution of final mediolateral balance at 0, 10, 30 and 90 degrees of flexion.

Figure 3

#5611

Can We Safely Release the Posterior Capsule During Total Knee Arthroplasty?

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Introduction

In total knee arthroplasty (TKA) the knee may be found to be too stiff in extension, causing a flexion contracture. One proposed surgical technique to correct this extension deficit is to recut the distal femur, but that may lead to excessively raising the joint line. Alternatively, full extension may be gained by stripping the posterior capsule from its femoral attachment, however if this release has an adverse impact on anterior-posterior (AP) stability of the implanted knee then it may be advisable to avoid this technique. The aim of the study was therefore to investigate the effect of posterior capsular release on AP stability in TKA, and compare this to the restraint from the cruciate ligaments and different TKA inserts.

Methods

Eight cadaveric knees were mounted in a six degree of freedom testing rig (Fig.1) and tested at 0°, 30°, 60° and 90° flexion with ±150 N AP force, with and without a 710 N axial compressive load. The rig allowed an AP drawer to be applied to the tibia at a fixed angle of flexion, whilst the other degrees-of-freedom were unconstrained and free to translate/ rotate. After the native knee was tested with and without the anterior cruciate ligament (ACL), a cruciate-retaining TKA (Legion; Smith & Nephew) was implanted and the tests repeated. The following stages were then performed: replacing with a deep dished insert, cutting the posterior cruciate ligament (PCL), releasing the posterior capsule using an osteotome (Fig. 2), replacing with a posterior-stabilised implant and finally using a more-constrained insert.

Results

In anterior drawer, only cutting the ACL caused a large increase in laxity compared to the native state (8 mm average across all flexion angles). At 0°, releasing the posterior capsule increased the laxity by 1.4 mm compared with cutting the PCL ($p < 0.05$), with no significance found at any other flexion angles. In posterior drawer with no compressive load, cutting the PCL significantly increased laxity at 30°, 60° and 90° (average 7 mm), however additional release of the posterior capsule only increased laxity by 1.5 mm and 0.8 mm at 0° and 30° respectively. At 30°, 60° and 90°, posterior stability was significantly restored by introducing a posterior-stabilised or more-constrained insert. When a 710 N compressive load was applied.

Conclusions

The most important finding of the study was that releasing the posterior capsule did not cause a clinically large difference in AP laxity in context with cutting the PCL. Therefore, releasing the posterior capsule to restore extension during TKA surgery could be considered a biomechanically safe option. In cases of posterior instability due to PCL and capsular damage, a posterior-stabilised insert can restore stability, particularly in mid to late flexion. Future studies could compare this data to isolated implant constraints, to help investigate how much stability is provided by the different implant geometries compared to the PCL and posterior capsule.

Figures

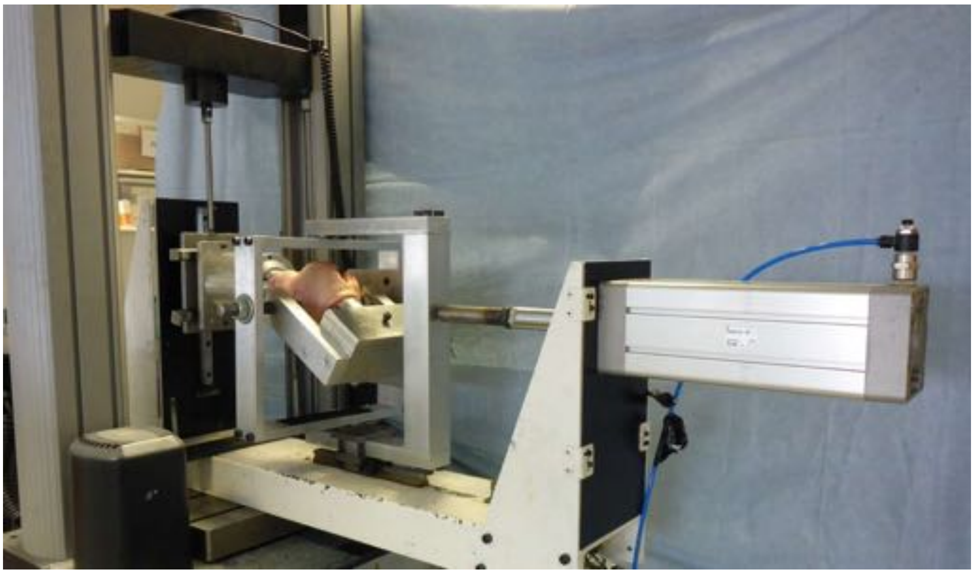

Figure 1

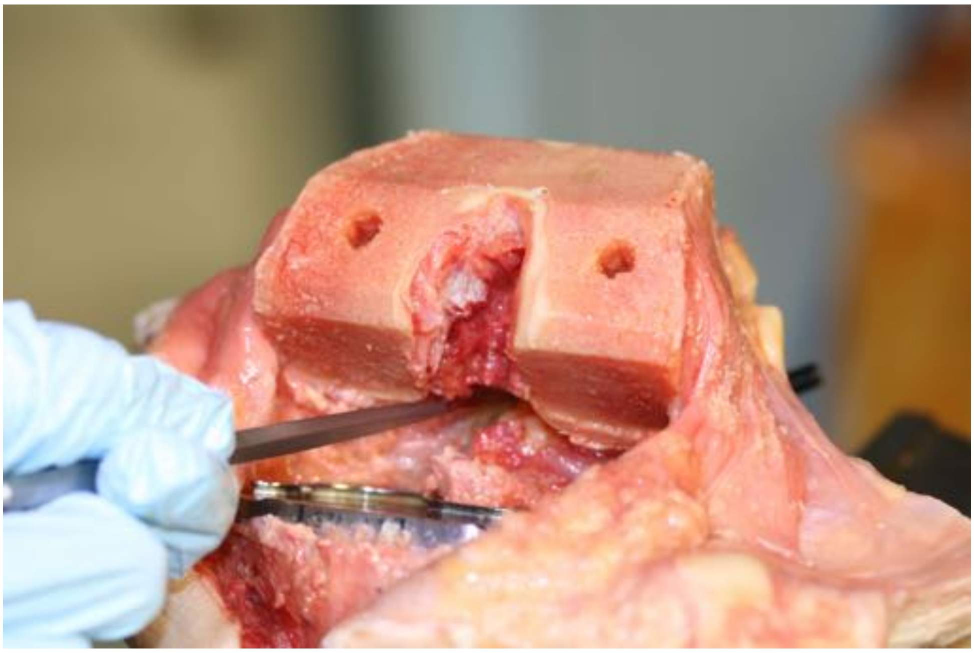

Figure 2

#5849

A Novel Algorithm to Balance Varus Knee Without Releasing Superficial MCL Based on the Pathological Changes in Varus Knee

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Introduction:

John Insall described medial release to balance the varus knee; the release he described included releasing the superficial MCL in severe varus cases. However, this release can create instability in the knee. Furthermore, this conventional wisdom does not correct the actual pathology which normally exists at the joint line, and instead it focuses on the distal end of the ligament where there is no pathology.

We have established a new protocol consisting of 5 steps to balance the varus knee without releasing the superficial MCL and we tried this algorithm on a series of 115 patients with varus deformity and compared it to the outcome with a similar group that we have performed earlier using the traditional Insall technique.

Material and method:

115 TKR were performed by the same surgeon using Zimmer Persona implant in varus arthritic knees. The deformities ranged from 15 to 35 degrees. First, the bony resection was made using Persona instrumentation as recommended by the manufacturer. The sequential balancing was divided into 5 steps (we will show a short video demonstrating the surgical techniques for each step) as follows:-

Step 1	**:**	**Releasing of deep MCL**
Step 2	**:**	**Excising of osteophyte**
Step 3	**:**	**Excising of scarred tissue in the posteromedial corner soft phytes**
Step 4	**:**	**Excision of the posteromedial capsule in case of flexion contracture**
Step 5	**:**	**Releasing the semi-membranous (in gross deformity)**

We used soft tissue tensioner to balance the medial and lateral gaps. When the gaps are balanced at early step, there was no need to carry on the other steps. We used only primary implant and we did not have to use any constrained implant. We have compared this group with a similar group matched for deformity from previous 2 years where the conventional medial release as described by Insall.

Results:

We could balance all knees without releasing the superficial MCL ligament as follows:

- **In**[H1] **31 cases, we were able to balance the knees performing step 1 and step 2 only**
- **In 35 cases, we had to do step three in addition to 1 and 2 to achieve balance of cases**

- **In 25 cases, we performed step 4- those cases had pre-operative flexion contracture**
- **We had to proceed to step 5 only in 14 cases. These patients had the worst deformity in the group**

We have used primary TKR in all cases; in 83 cases, we used a CR implant and in the rest, we used PS implant. Comparing this to the earlier conventional release we had to use 11 CCK implant on severe cases.

Patient satisfaction was better with the new algorithm group when compared with the traditional release

Preserving the superficial MCL allowed us to maintain stability post-operatively and allowed us to use minimum constraint such as CR in severe deformity.

Discussion:

Many literatures have confirmed that cutting superficial MCL causes major medial instability after TKA. Releasing or pie crusting the superficial MCL can cause MCL insufficiency. Our protocol enable the surgeon to tackle the pathology rather than take a short-cut and releasing the superficial MCL. Reserving the superficial MCL allowed us to use minimal constraint even in severe deformity of 40 degrees of varus deformity. The conventional release has resulted in some cases instability, forcing us to use higher constraint such as CCK.

Conclusion:

Although releasing the superficial MCL has been described in different ways in multiple literature, little attention has been paid to the pathology of the posteromedial corner. This paper clearly shows that the complex anatomy of the posteromedial corner require us to pay better attention and this paper present better algorithm reserving the superficial MCL and enabling us to correct the deformity and balancing the soft tissue without instability. We strongly recommend surgeons not to release the superficial MCL because this will create instability in some cases.

[H1]

#5788

The Extension Planning Angle in Gap Balancing Total Knee Arthroplasty Influences Mid-Flexion Laxity

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Introduction: The aim of gap-balancing in total knee arthroplasty (TKA) is to produce equal and symmetric gaps throughout the range of motion (ROM). The technique references the native flexion and extension gaps to plan the femoral bone resections to achieve a balanced knee. However, the native tibiofemoral gaps are significantly different between 0^o and 10^o of flexion [1,2]. Therefore, planning for equal and symmetric gaps at 0^o and 90^o of flexion could result in a different femoral plan, and thus a different knee laxity profile throughout flexion, including in mid-flexion, than when planning at 10^o and 90^o of flexion. This study therefore aims to quantify the change in the post-operative tibiofemoral gap throughout the ROM when varying the planning extension angle between 0 and 10 degrees flexion.

Methods: 40 patients (mean age: 71±10, BMI: 28.6±7.7) undergoing robotic-assisted TKA were included. After resecting the tibia, the knee joint was tensioned using a computer-controlled ligament tensioning tool (Fig. 1). The system applied a load ranging between 80-100N of tension equally to the medial and lateral compartments as the limb was manually taken through a ROM. The femoral implant position and size was then planned to have equal and symmetric knee gaps in extension and flexion. Patients were divided into two sequential groups: Group-A, the knee was planned to have equal and symmetric gaps at 0^o and 90^o (18 knees), Group-B the knee was planned to have equal and symmetric gaps at 10^o and 90^o (14 knees). The femur was resected, and a femoral trial was inserted and the postoperative gaps were measured throughout the ROM while the tensioning tool applied equal tension to the ligaments. Mean and standard deviation of the post-operative gaps were calculated for each group. T-tests were used to identify significant differences between the two groups.

Results: In both group-A and group-B, the post-operative extension and flexion gaps were balanced to within 1mm of each other on average (Fig. 2). Significantly larger gaps were seen in mid-flexion for group-A than for group-B however, with a maximum laxity increase of 3-4mm occurring around $25\text{-}30^o$ in group A. The gap profiles between 20-60^o were significantly different from the gaps at the extension and flexion planning angles in group-A, but not in group-B.

Discussion: Gap planning at 10^o of flexion produced equal and symmetric gaps from $10\text{-}90^o$ that were similar in patterns to those reported in the native knee [1]. Gap planning at 10^o resulted in smaller gaps and increased tension at full extension, however, which may result in a flexion contracture requiring a posterior capsule release or distal femoral recut to achieve full extension. Planning at 0^o resulted in larger gaps and lower joint forces at full extension, but increased knee laxity in mid-flexion which may contribute to mid-flexion instability. Depending on the clinical circumstances of the case, the implications of planning at both 0^o and 10^o in gap balancing TKA should be taken into consideration.

References: [1] Moschetti et al. *ORS* 2017. [2] Roth et al. *J Bone Joint Surg Am*. 2015, 97(20):1678

Figures

Figure 1: Intra-operative photo showing the Active Spacer inserted in the knee

Figure 1

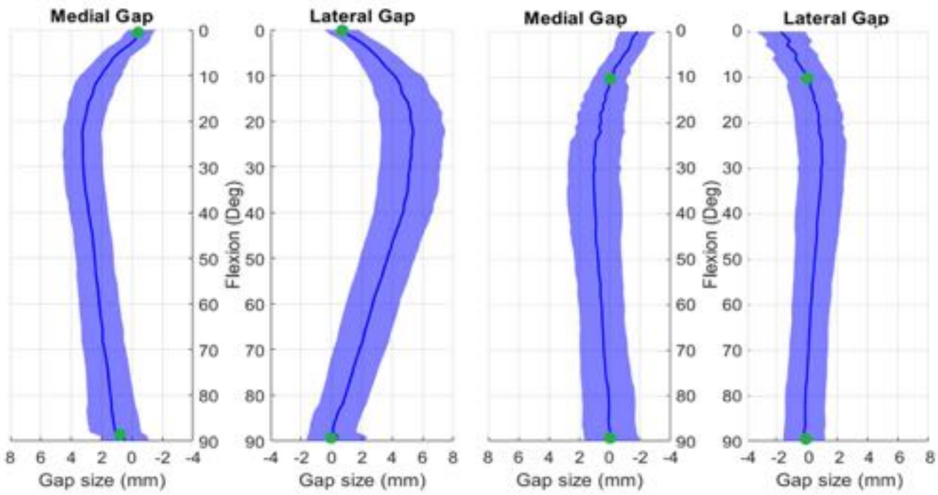

Figure 2: Post-operative gap profiles measured in knees that were planned to have equal gaps at 0° and 90° (left, Group A) and at 10° and 90° (right, Group B)

Figure 2

#5593

Does a Difference in the Rotational Position of the Ligament Balancer Affect Medial and Lateral Soft Tissue Balance in TKA?

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Soft tissue balance is important for good clinical outcome and good stability after TKA. Ligament balancer is one of the devices to measure the soft tissue balance. The objective of this study is to clarify the effect of the difference in the rotational position of the TKA balancer on medial and lateral soft tissue balance.

[Materials and Methods]

This study included with 50 knees of the 43 patients (6 males, 37 females) who had undergone TKA with ADLER GENUS system from March 2015 to January 2017. The mean age was 71.1±8.1 years. All patients were diagnosed with medial osteoarthritis of the knee. All implants was cruciate substituted type (CS type) and mobile bearing insert.

We developed a new ligament balancer that could be fixed to the tibia with keel and insert trial could be rotated on the paddle. We measured the medial and lateral soft tissue balance during TKA with the new balancer. The A-P position of the balancer was fixed on tibia in parallel with the Akagi line (A-P axis 0 group) and 20 degrees internal rotation (IR group) and 20 degrees external rotation (ER group). Soft tissue balance was measured in extension and 90 degrees of knee flexion on each rotational position.

[Results]

The mean angle of valgus and varus in IR group, 0 group and ER group were 4.6±2.2 degrees varus, 1.9±1.6 degrees varus and 0.4±2.4 degrees varus respectively in extension, and 5.5±3.0 degrees varus, 2.1±2.2 degrees varus and 0.7±3.2 degrees varus respectively in 90 degrees of knee flexion. There were significant differences between three groups in extension ($p<0.0001$) and flexion ($p<0.0001$). In other words, when the balancer was fixed on tibia with internal rotation against the Akagi line, the soft tissue balance indicated medial tightness. Conversely, when the balancer was fixed on tibia with external rotation against the Akagi line, the soft tissue balance showed lateral tightness.

The insert trial significantly rotated to opposite side against the position of balancer fixed.

[Discussion]

Ligament balancer is used to be inserted between femur and tibia. If balancer is not fixed on tibia, it may rotated and translated during measurement. That movement made impossible to measure the correct soft tissue balance. We created a new balancer that could be fixed to the tibia with keel and the insert trial could be rotated on the paddle. Furthermore, it is possible to measure the soft tissue balance after installation of the femoral trial. As a result, it is possible to check the real soft tissue balance after implantation.

In conclusion, direction of A-P axis of the ligament balancer is important to measure the correct soft tissue balance in TKA. This result means that the implantation on excessive rotation of the tibial component affects on the medial and lateral soft tissue balance in fixed type TKA. In mobile type TKA, it is possible to substitute if it is within the possible range of rotation by rotational mobile insert.

#6033

Combining Multiple Technologies to Achieve Optimized Surgical Outcomes

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Introduction & Aims – Many new technologies have been introduced in total knee arthroplasty (TKA) to reduce the clinical and radiographic outliers as well as to address the 20% patient dissatisfaction rate following TKA. Computer assisted surgery tools to either guide or verify the cutting planes have evolved to robotic techniques that not only guide the cuts, but allow fine-tuned, patient specific planning of component placements. Most recently, quantitative intra-operative load sensors have been added to further assess the variability and non-linearity of the soft-tissue envelope, which plays an important role in the stability and function post-operatively. The purpose of this study was to combine the use of robotics and load sensors to optimize the surgical outcomes of TKA.

Method – A cohort of 17 consecutive TKAs were performed with robotics (pre-operative patient specific planning, intra-operative plan adjustments and intra-operative robotic guidance) followed by intra-operative load sensing during the trialing phase. Pre-operative CT scans were reconstructed of each patient with the component placement plan based on bony anatomy. Intra-operatively, but before bony cuts were made, the plan was adjusted (with both tibial and femoral plans available for modification) driven by achieving equal gap spacing in flexion and extension, where the gap spacing is the measurement of the distance between the predicted cut bony surfaces. During trialing, an instrumented tibial trial component was inserted that captured the medial and lateral tibiofemoral loads, allowing the quantitative assessment of the state of balance through the range of motion. As previously reported, an absolute mediolateral load differential of less than 15 lbf was characterized as balanced. Guided by this feedback, several techniques were utilized to achieve balance. This observational study reports on these findings.

Results –The ratio of knees that had a pre-operative varus deformity compared to a valgus deformity was 56%/44%. After robotic bony preparation resulted in equal gap spacing, only 44% of the knees were quantitatively balanced, which was independent of pre-operative deformity (44% of varus knees were balanced versus 43% of valgus knees). However, the imbalance in the valgus knees was more predictable with 100% of the unbalanced valgus knees having higher lateral loads. In the unbalanced varus knees, 1 had higher medial loads throughout flexion, 2 had higher lateral loads throughout flexion and 1 had higher lateral loads in extension and higher medial loads in flexion. Three approaches (not mutually exclusive) were used to achieve balance following load feedback; robotically guided bony recuts (11%), soft tissue adjustments (67%) and final component adjustments as the cement cured (100%, 67% tibia only and 33% both femur and tibia).

Conclusions – Combining multiple technologies in TKA allows the optimization of both patient specific component placement and soft tissue driven adjustments to create well aligned, well balanced surgical outcomes. Intra-operative load feedback provided guidance for multiple balancing techniques, including the use of robotic to make fine bony cut adjustments. Clinical follow-up is clearly required to determine the clinical consequences of these optimized surgical outcomes.

#5624

Implant Realignment: An Alternative to Ligamentous Release in TKR Balancing

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ABSTRACT

Background

Intraoperative balancing can be accomplished by either more prevalent but less predictable soft tissue releases, implant realignment through adjustments of bone resection or a combination of both. There is no published study directly comparing these methods.

Objective

To provide a direct comparison between implant realignment and traditional ligamentous release for soft tissue balancing in total knee arthroplasty using both objective kinematic sensor data to document final balance and patient reported outcomes.

Methods

IRB Approved retrospective cohort study of prospectively collected data comparing kinematic sensor data and patient reported outcomes for all consecutive patients that underwent TKA utilizing kinematic sensors with or without robotic assistance performed between August 2012 to April 2017 to allow for a minimum of 12 months clinical follow up.

Results

107 knees met inclusion criteria. Component realignment was utilized more frequently in the robotic surgical technique cohort than the non-robotic, non-navigated cohort due to the increased precision in implant realignment possble. Although KSS and FJS scores showed equivalent outcomes at both the 3-month and 1-year time points, KSS-Function scores at 1-year showed a statistically and clinically significant increase of 11.89 points in the implant realignment cohort compared to the ligamentous release cohort.

Conclusions

A statistically and clinically significant improvement in KSS-Function scores benefiting the implant realignment technique was seen at 1-year post-operatively. This may suggest a benefit to using implant realignment as the ideal balancing strategy in total knee arthroplasty. Further longitudinal studies with increased number of cases should increase statistical power which is needed to further confirm the suggested benefits of the implant realignment balancing technique.

#5743

What Is an Acceptable Failure Rate for a New Spinal Growing Rod?

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What is an acceptable failure rate for a new spinal growing rod?

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Abstract

Background

Established hip and knee arthroplasty registers exist in many countries but this is not the case with spinal implants. Moreover, in the case of a rod intended to guide spinal growth in a child and then be removed, the definition of 'failure' (revision) used for hip or knee arthroplasty is inappropriate. How can the performance of such spinal implants be judged?

Methods

Ninety-six MAGnetic Expansion Control (MAGEC) spinal rods were obtained from multiple centres after removal from the spines of 52 children with scoliosis. Clinical details were assessed and divided between unplanned revision operations ('failures') and those which were planned. Of the explanted rods, 49 were tested for the amount of force they could output, using the manufacturer's supplied test jig. Sixty-five rods were cut apart so that the internal components (bearings, O-ring seals, drive pins) could be assessed, alongside if there was evidence of internal wear.

Results

Seventy-four per cent of revision operations were unplanned. Eighty per cent of explanted rods were unable to produce the force expected from a new rod. All rods (100%) that were successfully cut open showed signs of internal wear. Non-functional bearings were seen in 74% of cases, obvious seal damage in 57% of cases and broken drive pins in 47% of cases.

Conclusion

Despite potential clinical benefits, explanted MAGEC rods showed consistent and substantial damage. The majority of rods showed zero force output and most revision operations were unplanned. Independent explant analysis allows appraisal of new technology in arthroplasty for patient benefit.

Keywords: growing rod, explant, failure analysis, early onset scoliosis, MAGEC, wear.

#5696

LP ESP Elastomeric Lumbar Total Disc Replacement : Five Year Follow-Up for Clinical and Radiological Outcomes

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Introduction:

Lumbar total disc replacement (TDR) is an alternative treatment to avoid fusion related adverse events, specifically adjacent segment disease. New generation of elastomeric non-articulating devices have been developed to more effectively replicate the shock absorption and flexural stiffness of native disc. This study reports 5 years clinical and radiographic outcomes, range of motion and position of the center of rotation after a viscoelastic TDR.

Material and methods:

This prospective observational cohort study included 61 consecutive patients with monosegmental TDR (fig 1). We selected patients with intermediate functional activity according to Baecke score. Hybrid constructs had been excluded. Only cases with complete clinical and radiological follow-up at 3, 6, 12, 24 and 60 months were included. Mean age at the time of surgery was 42.8 $\pm$7.7 years-old (27â€60) and mean BMI was 24.2 kg/m² $\pm$3.4 (18-33). TDR level was L5-S1 in 39 cases and L4-L5 in 22 cases.

The clinical evaluation was based on Visual Analog Scale (VAS) for pain, Oswestry Disability Index (ODI) score, Short Form-36 (SF36) including physical component summary (PCS) and mental component summary (MCS) and General Health Questionnaire GHQ28. The radiological outcomes were range of motion and position of the center of rotation at the index and the adjacent levels and the adjacent disc height changes.

Results:

There was a significant improvement in VAS (3.3±2.5 versus 6.6±1.7, p <0.001), in ODI (20±17.9 versus 51.2±14.6, p <0.001), GHQ28 (52.6±15.5 versus 64.2±15.6, p <0.001), SF 36 PCS (58.8±4.8 versus 32.4±3.4, p <0.001) and SF 36 MCS (60.7±6 versus 42.3±3.4, p <0.001).

Additional surgeries were performed in 5 cases. 3 additional procedures were initially planified in the surgical program: one adjacent L3-L5 ligamentoplasty above a L5S1 TDR and two L5S1 TDR cases had additional laminectomies. Fusion at the index level was secondary performed in 2 L4L5 TDR cases but the secondary posterior fusion did not bring improvement. In the 56 remaining patients none experienced facet joint pain. One patient with sacroiliac pain needed local injections.

Radiological outcomes were studied on 56 cases (exclusion of 5 cases with additional surgeries) (fig 2,3).

The mean location centers of the index level and adjacent discs were comparable to those previously published in asymptomatic patients. According to the definition of Ziegler, all of our cases remained grade 0 for disc height (within 25% of normal)

Discussion:

The silent block design of LP-ESP provides an interesting specificity. It could be the key factor that makes the difference regarding facets problems and instability reported with other implants experimentally or clinically. Unfortunately no other comparative TDR series are available yet in the literature.

Conclusion: This series reports significant improvement in mid-term follow up after TDR which is consistent with previously published studies but with a lower rate of revision surgery and no adjacent level disease pathologies. The radiographic assessment of the patients demonstrated the quality of functional reconstruction of the lumbar spine after LP ESP viscoelastic disc replacement.

Figures

Figure 1

Figure 1

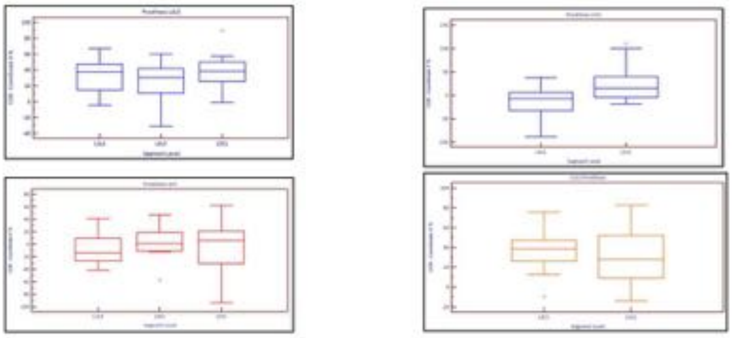
Figure 2 :

Follow-up 1,2 and 5 years : ROM at the implanted and adjacent levels

		L5 S1 TDR			L4 L5 TDR		
	Follow up (Yrs)	L5S1	L4L5	L3L4	L5S1	L4L5	L3L4
	1	5.9 (4)	8.7 (5.8)	9.4 (4.9)	6.7 (4.3)	5.8 (3.9)	10.5 (4.7)
	2	6.4 (3.3)	6.2 (5.8)	8.6 (5.7)	7.4 (5.2)	7.8 (4.3)	8.3 (5.3)
ROM ° mean (SD)	5	7.2 (3.3)	8.5 (4.8)	8.5 (4.6)	8.8 (5.1)	7.3 (4)	8,2 (4.5)

Figure 2

Figure 3 :
X and Y coordinates of the MCR at the implanted and the adjacent levels. (Origin = upper posterior angle of the lower vertebral body; Unit = length of the upper endplate of the lower vertebral boy).
A : L4-L5 cases ; B : L5-S1 cases.



A

B

Figure 3

#5927

CP ESP Viscoelastic Cervical Disk Replacement : 2 Years Follow-Up With Clinical and Radiological Results . Evolution of Segmental Mobility and Location of Mean Centers of Rotation.

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Introduction:

The viscoelastic cervical disk prosthesis CP-ESP is an innovative one-piece deformable but cohesive interbody spacer. It is an evolution of the LP-ESP lumbar disk implanted since 2006. The implant provides 6 full degrees of freedom including shock absorption. The design allows a limitation for rotation and translation with resistance to motion (elastic return property) aimed at avoiding overload of the posterior facets. The rotation center can vary freely during motion. It thus differs substantially from current prostheses.

This study reports the clinical results of a prospective observational study series of 89 patients who are representative of the current use of the ESP implant since 2012.

The radiological results are focused on the evolution of the mean center of rotation (MCR) as an additional information to the range of motion (ROM) for the evaluation of the quality of spine movement.

Material and methods

89 patients (33 males, mean age 45 years [28-60], 107 implants) were included for an open,

prospective and non-randomized study between October 2012 and December 2015 (follow up controls at 3, 6, 12 and 24 months).

One level patients were at C3C4 (3),C4C5 (3), C5C6 (41) C6C7 (24) C7T1 (1)

Two levels patients were C4C5/C5C6 (3), C5C6/C6C7 (12) , C6C7/C7D1 (1) and 3 levels C4C5/C5C6/C6C7 (1)

Results

Clinical results are reported in fig1.

We did not observe local ossifications.

One case of side level degeneration was observed after 12 months in a C5C6 mono-segmental disk replacement (retrospectively this patient was a good case for a double initial implantation). To date the patient has not been re-operated.

Two cases were revised (one C5C6 implant for bone ingrowth failure at 6 months and one C4C5 case for painful hypermobility in a globally stiff spine).

Range of motion was obtained after 6 months and maintained at 24 months.(fig 2)

Radiological study of the location of the mean center of rotation at the prosthesis level and adjacent disks demonstrated the adaptation ability of the implant (fig 3).

Conclusion

The concept of the ESP prosthesis is different from that of the “first generation” articulated devices currently used in the cervical spine. This study reports encouraging clinical results about pain, function and kinematic behavior.

An interesting point is the evolution of the Mean Centers of Rotation in the

post-operative course. This adaptation ability is one of the main features as we need to consider the mean and long term evolution of the global cervical posture and mobility after a cervical disc replacement.

Additional studies and longer patient follow-up are needed to assess long-term reliability of this innovative implant.

Figures

Figure 1

M±SD	PRE OP	3 M	6 M	12 M	24 M
VAS neck score (/10)	6,42	3,08	2,18	2,62	2,40
VAS arm score (/10)	6,57	3,13	1,94	2,97	1,84
Motor test (/5)	4,5	4,9	5	5	4,97
Sensory test (/5)	2,7	2,9	3	2,98	2,97
NDI (%)	55,5±17,1	33,8±17	24,9±18,1	26,3±19,5	20,2±17,5
NDI points	27,3±9,1	16,8±8,5	12,4±9,1	13,1±9,7	9,9±8,5
SF 36 PCS score	31,9	47,4	58,2	57	64,1
SF 36 MCS score	31,4	51,5	59,1	58,7	62,6

Figure 1

Figure 2

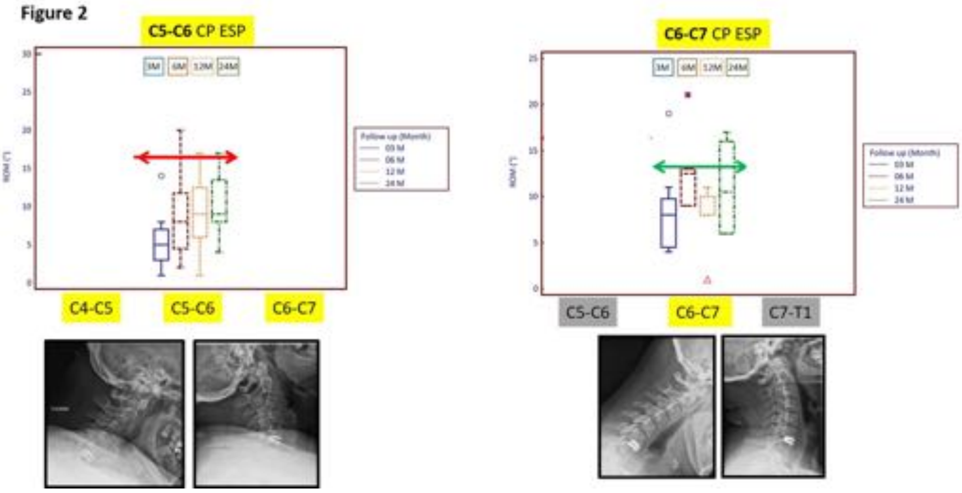

Figure 2

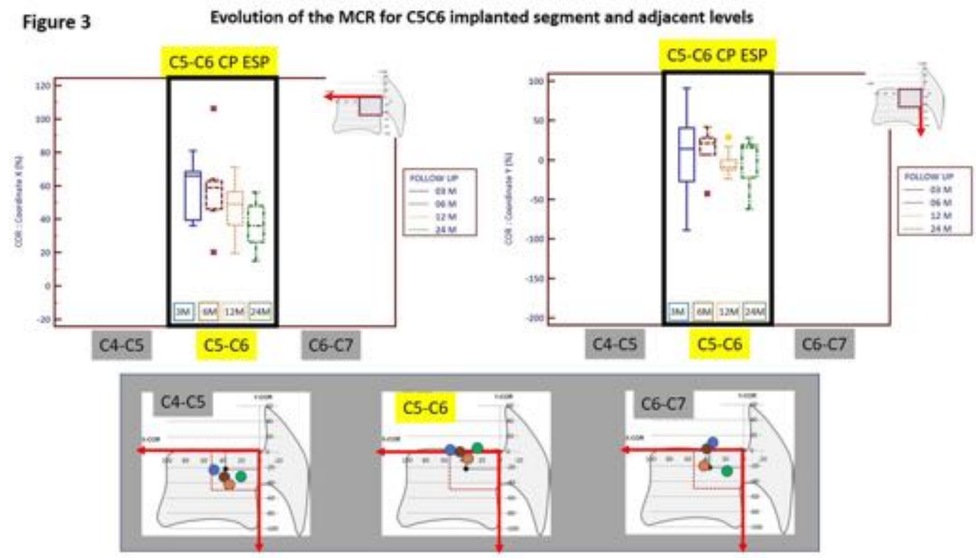
Figure 3
Evolution of the MCR for C5C6 implanted segment and adjacent levels
C5-C6 CP ESP
C5-C6 CP ESP
3M
6M
12M
24M
C4-C5
C5-C6
C6-C7
C4-C5
C5-C6
C6-C7
C4-C5
C5-C6
C6-C7

Figure 3

#5828

Polyethylene Inserts in Ankle Arthroplasty: A Factor in Revision Rate?

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Introduction: While advances in joint-replacement technology have made total ankle arthroplasty a viable treatment for end-stage arthritis, revision rates for ankle replacements are higher than in hip or knee replacements [1]. The questions asked in this study were (1) what retrieved ankle devices demonstrate about ankle arthroplasty failures, and (2) how do these failures compare to those seen in the hip and the knee?

Materials and methods: An IRB-approved retrieval laboratory received retrieved polyethylene inserts and surgeon-supplied reason for revision from 68 total-ankles (6 designs, including four currently-marketed designs) from 2002 to the present. All retrievals were rated for clinical damage. Polyethylene inserts received six months or less after retrieval (n=47) were analyzed for oxidation using Fourier Transform Infrared (FTIR) spectroscopy, reported as maximum ketone oxidation index [2]. Insert sterilization method was verified using trans-vinylene index [3]. Statistical analysis was performed using nonparametric Spearman's correlation (IBM SPSS v.22).

Results: The ankle devices were retrieved most commonly for loosening (n=20) followed by polyethylene fracture (n=12). These failure modes occurred after statistically different in vivo time (loosening: median=43.6 months; polyethylene insert fracture: median=88.7 months; Spearman's rho=0.538, p=0.001). Presence of clinical fatigue (cracking and/or delamination) was identified in 24 of the 68 retrieved inserts, and its presence correlated with in vivo time (Spearman's rho =0.437, p<0.001). Twelve of these fatigued inserts were analyzed by FTIR. TVI analysis confirmed the sterilization method of the fatigued inserts: 11 gamma, 1 non-gamma sterilized. All 12 fatigued inserts had maximum ketone oxidation index (KOI) of 1.2 or higher (Figure 1). Presence of fatigue correlated with measured oxidation (Spearman's rho =0.702, p<0.001). Eight of the 12 inserts that fractured in vivo were analyzed by FTIR (Figure 2). All were gamma-sterilized, and all had oxidation of 1.2 or higher. Oxidation measured in 47 of the ankle inserts was compared to oxidation rates previously published for gamma-sterilized hip and knee polyethylene retrievals (Figure 3).

Discussion: This retrieval study concurs with the ankle arthroplasty literature that loosening is the most common reason for ankle revision [4]. Ankle inserts retrieved as a result of implant loosening had lower oxidation and no fatigue damage resulting from their shorter in vivo time. Fatigued and/or fractured inserts were in vivo for longer times, allowing more oxidation to occur. The effect of oxidation on polyethylene tensile strength and ductility has been reported for tibial inserts [5]. Oxidation above the critical value [5] has a dramatic effect on the ability of the polyethylene to resist fatigue damage and fracture, since the toughness of the polyethylene drops to near zero. All fatigued and fractured ankle inserts had oxidation that exceeded this critical oxidation. Most ankle inserts, whether gamma or non-gamma sterilized, oxidized at or above the oxidation rates previously published for gamma-sterilized hip and knee polyethylene retrievals [6].

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Figures

Figure 1: Ankle inserts retrieved with fatigue damage have oxidation that is at or above critical oxidation.

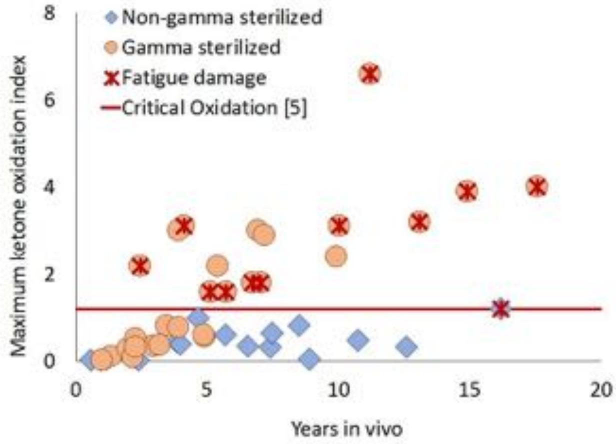

Figure 1

Figure 2: Ankle inserts that fractured in vivo have oxidation above critical oxidation. All fractured inserts were gamma-sterilized, many likely gamma-air sterilized.

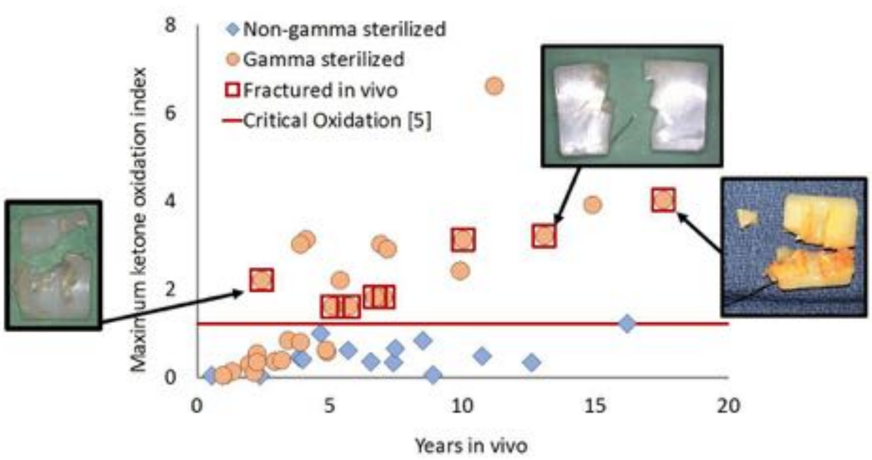

Figure 2

Figure 3: Oxidation measured in retrieved ankle inserts is compared to previously published oxidation rate measured in retrieved gamma-sterilized hips and knees [6] and oxidation measured in never-implanted, shelf-aged gamma-air sterilized tibial inserts.

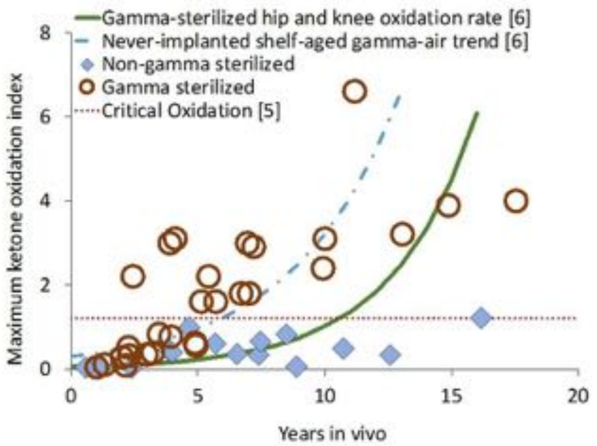

Figure 3

#6157

Medial and Lateral Malleoli Impose Anatomical Constraints on Total Ankle Arthroplasty Design

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INTRODUCTION

Contemporary total ankle arthroplasty (TAA) techniques reconstruct the tibiotalar articulation while preserving the medial and lateral malleoli. The malleoli place anatomic constraints on the design of the talar component of the TAA system. If these constraints are not respected, then proper placement of the talar component may be compromised intra-operatively, or unintended contact between the prosthesis and bone may occur post-operatively. The goal of this study was therefore to quantify the medial and lateral malleolar boundaries.

METHODS

The orientation of the talus from a frontal view was quantified based on CT scans of left leg, non-arthritic specimens (n=89; 52M/37F) (Figure 1). The talar dome was identified as the portion of the talus superior to the talar neck. The frontal profile of the dome defined by a plane positioned through the medial and lateral high points was extracted for each specimen. Statistical shape analysis was performed to identify the modes of variation of the frontal profile. Medial and lateral lines were fit to each profile, and resulting angles relative to the superior-inferior axis were measured. A paired student t-test ($P<.05$) was used to assess differences between the medial and lateral malleolus.

RESULTS

Figure 2 shows the average frontal profile of the talar dome, as well as ±1 and ±2 standard deviations. The medial and lateral taper angles of the talus were 18.7° ± 6.1° and 12.0° ± 4.6°, respectively, with the lateral taper angle being significantly smaller than the medial taper angle ($P<.001$). The medial taper increased with talus size (as measured by the medial-lateral width of the dome) whereas the lateral taper decreased with talus size (Figure 3), though both regressions were weak ($R^2 < 0.1$)

DISCUSSION

Restoration of the bicondylar articulation geometry of the tibiotalar joint is an important design goal for TAA. One aspect of this geometry is the anatomic constraints imposed by the medial and lateral malleoli, to minimize unexpected impingement of the TAA prostheses with surrounding anatomic structures. Here, we have quantified those constraints through analysis of the medial and lateral taper of the talus, showing an increased taper angle on the medial side of the talus as compared to the lateral side.

Figures

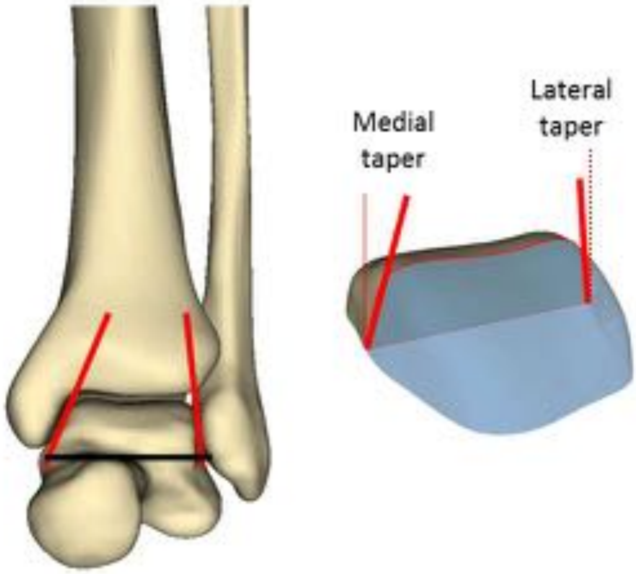

Figure 1: *(Left) Schematic of the medial and lateral taper angles of the talar dome. (Right) Talar dome with medial and lateral taper angles of the frontal profile identified.*

Figure 1

Figure 2: *Average dome profile (black) and ±1 and 2 standard deviations of the first mode of variation.*

Figure 2

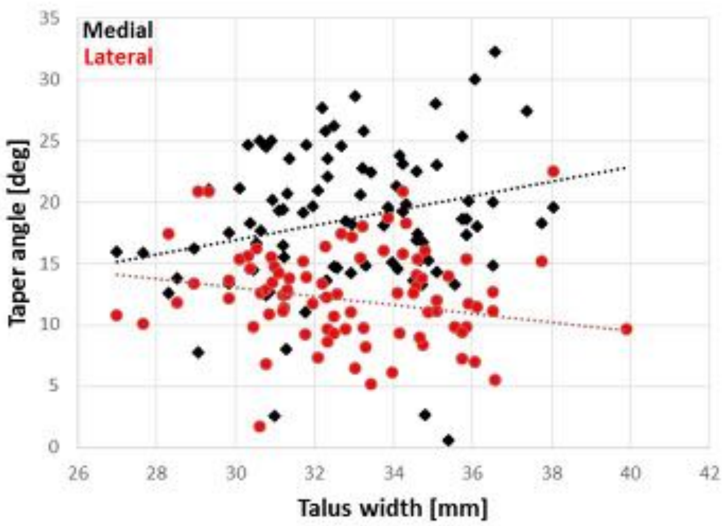

Figure 3. *Medial (black) and lateral (red) talus taper angles, as functions of talus medial-lateral width.*

Figure 3

#5934

Trends in Primary and Revision Cervical Disc Arthroplasty Utilization Within the Medicare Database

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INTRODUCTION: Cervical Disc Arthroplasty (CDA) is a proposed treatment for cervical radiculopathy. Currently, there is a paucity in the literature regarding the trends of utilization of primary CDA compared to the revision procedure. The purpose of this study was to determine annual trends of primary CDA by analyzing an administrative database. The study hypothesizes that primary CDA and revision CDAs have been increasing.

MATERIALS AND METHODS: A retrospective review from 2005 – 2014 was performed using the Medicare Standard Analytical Files from the PearlDiver supercomputer (PearlDiver Technologies, Fort Wayne, IN). All patients undergoing primary CDA were queried using the International Classification of Disease, ninth revision (ICD-9) and Current Procedural Terminology codes 84.62 and 22856, respectively. Patients undergoing revision CDA were queried using ICD-9 procedural code 84.66. Statistical analysis was primarily descriptive and was performed using the programming language R (University of Auckland, New Zealand). Calculated annual growth rate (CAGR) was used to determine the average annual growth of primary CDAs and revision CDAs performed. Pearson's correlation coefficient (r) was calculated to compare utilization trends between the primary and revision CDA. Additionally, length of stay (LOS) and day of surgery costs for each age group were also analyzed. Significance was defined as $p<0.05$.

RESULTS: From 2005 – 2014, there were 2,016 primary CDA (female = 1,104; male = 912) procedures performed compared to 517 revision CDA (female = 265; male = 252) procedures performed. The CAGR of primary CDAs was 20.54% compared to 5.84% with revision CDAs (r = 0.5241, p = 0.119). (Figure 1). Patients under the age of 64 compromised majority of the population undergoing primary CDA (59.02%), having a CAGR of 24.07% (Figure 2) The primary procedure was commonly performed most commonly in the South (n = 851), followed by the West (n = 438), Midwest (n = 403), and Northeast (n = 321). Patients <64 had an average LOS of 1.77 days (d) ± 2.73 whereas patients in the age cohorts of 65 – 69, 70 – 74, 75 – 79, 80 – 84, and >85 had average LOS of 2.04d ± 3.68d, 2.26d ± 3.32d, 3.03d ± 5.47d, 5.75d ± 5.63d, and 4.37d ± 4.95d; respectively. Day of surgery costs increased as patients

CONCLUSION: Utilization of CDA has been shown to be increasing through the recent years due its effectiveness in treating cervical radiculopathy. The study highlights that primary CDA is a safe procedure as annual primary CDA procedures are surpassing those of revision CDA rates.

Figures

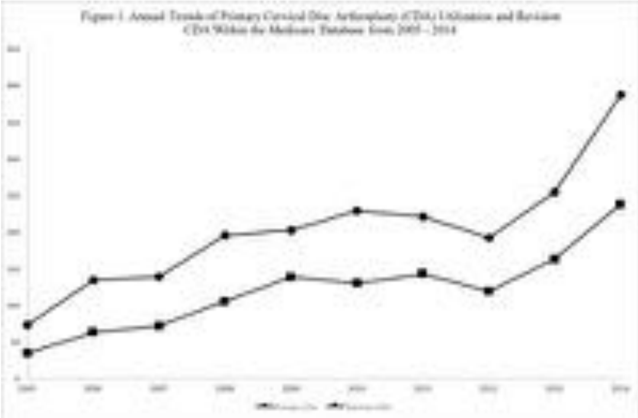

Figure 1

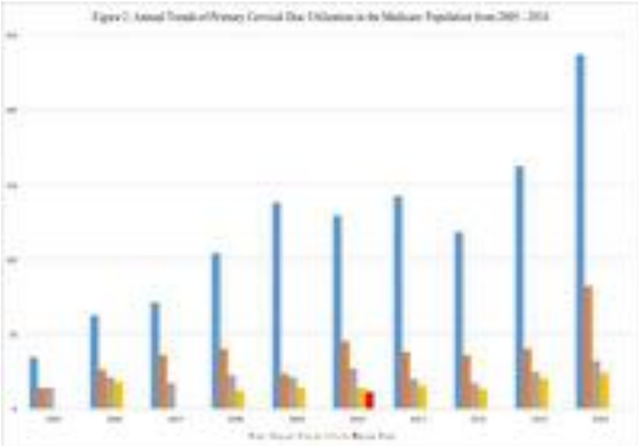

Figure 2

#6057

Does Acromion Anatomy Affect Acromion Stress Fracture After Reverse Shoulder Arthroplasty?

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Introduction

Acromial fractures after reverse shoulder arthroplasty (RSA) have been reported to leave patients with inferior clinical outcomes and greater risk of revision surgery. Because RSA alters normal anatomic relationships, the resulting forces of the deltoid alter physiologic stress patterns in the acromion. Other reasons for reaching this critical stress could be altered stresses patterns in an osteoporotic patient, wear to the acromion before surgery, or patient specific anatomic factors. The purpose of this study was to evaluate the effect of acromion size on the stress levels and increased risk of fracture at the acromion after RSA.

Methods

A 3D musculoskeletal kinematic combined finite element analysis (FEA) was performed to examine the effects of acromion size on fatigue life of the scapula after an RSA. The well-validated DSEM shoulder model implemented on OpenSim platform was used as the 3D kinematic simulation solver and Abaqus/standard 6.14-1 was used for FEA. Four lateralized RSA shoulders with different acromial sizes (ranging from -5.0 mm to +5.0 mm) (Figure 1) were compared with a standard implanted lateralized RSA model (Case 5). These range of acromion sizes are in line with clinically measured data for standard male scapula (31.9 ±4.7 mm). Kinematic simulation, magnitude and directional vector of muscle forces in every muscle strand were carefully measured following the International Society of Biomechanics (ISB) recommended guidelines. An FEA model was then constructed for each case with the information obtained from the kinematic analysis. The quasi-static analysis with Abaqus/standard was carried out to determine the highest minimum principal stress (HMPS) for each case, which was used to predict fatigue life percentage (FLP) of the acromion under the compressive cyclic loading.

Results

Our results are shown relative to the average-sized acromion, represented as 0 mm (case 5). For smaller acromion sizes of – 5 mm (case 1) and -2.5 mm (case 2), the HMPS was found to be 1.87 and 1.24 times higher than the average one, respectively. When larger acromion sizes were considered, HMPS at the +2.5 mm (case 3) was 0.95 times the average one, whereas HMPS at +5 mm (case 4) was 1.04 times higher than the average one. According to our model, the highest FLP was seen when the acromion size was +2.5 mm (case 4 - 178%) and the lowest FLP was seen when it was -5 mm (case 1 - 0.06%) (Figure 2).

Discussion

Strategies for preventing acromial fractures include optimizing patient’s bone health, correct glenoid baseplate screw length and position, and avoiding excessive deltoid tensioning. The goal of our study was to idenitify optimal and at risk acromial sizes which would result in excessive deltoid tension and ultimately fracture. It can be observed that larger acromion size generally benefits the fatigue life of an RSA shoulder by reducing its HMPS however the optimal balance appears to be at +2.5 mm for standard lateralized RSA, which can be understood as a bell-shaped curve. Surgeons must be aware of acromion size and deltoid tensioning when selecting optimal implant designs and sizes for RSA.

Figures

Figure 1. The acromion size is parametrized in an increment of 2.5 mm relative to the average one. In each panel, the maroon represents the average-sized acromion (Case 5) while the gray represents the parameterized acromion.

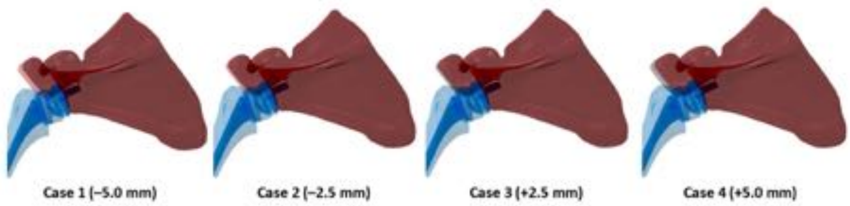

Figure 1

Figure 2. Comparison of the predicted fatigue life of RSA shoulder for each case. It is expressed as the percentage of the fatigue life of the average-sized RSA shoulder (Case 5).

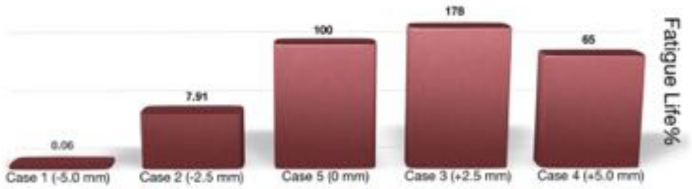

Figure 2

#5614

Trabecular Titanium - Cement Interface Characterization

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Introduction

Thanks to its 10 years clinical heritage, Trabecular Titanium^{TM} 3D printed porous structure for join prosthesis is nowadays recognize as one of the best option for cement-less bone ingrowth applications. Its higher coefficient of friction, higher porosity, reduced modulus of elasticity compared to other implants lead to improved primary and secondary stability. Trabecular Titanium^{TM} porous structure is characterized by multi-planar regular hexagonal interconnected cells, thereby its high open porosity may represent a potential interface for cement adhesion in cemented application. The aim of this study is to characterize the Trabecular Titanium^{TM}-cement interface during static conditions.

Materials and methods

Metal cylinders made by EBM technology were produced in size and shape suggested by ASTM F1147 and ASTM F1044 and cemented with standard bone cement (CMT1). Two different adhesion combination were tested: Trabecular Titanium^{TM}-on-Trabecular Titanium^{TM} porous structure (TT-TT) and Trabecular Titanium^{TM}-on-Sandblasted finishing with Ra3÷6 (TT-SB). For each test samples preparation was conducted as following: a) sample and counter-sample were positioned inside the adhesion equipment (Figure 1); b) bone cement was prepared observing the bone cement surgical technique; c) each assembly was loaded to have a cement thickness of 1±0,4mm. Load was maintained for 30 minutes. Static tensile adhesion test was performed according ASTM F1147 at a loading rate of 2,5 mm/min. Static shear adhesion test was performed according ASTM F1044 at a loading rate of 2,5 mm/min (Figure 2). Static torsion adhesion test was performed according to Beckmann[1] at a fixed rotational rate of 30°/min. Each test was repeated on seven samples. The test was run until the separation of the samples. Load was applied with MTS hydraulic actuators. Failing stress [MPa] was calculated according to ASTM F1147 and F1044, while rotational stiffness was calculated according to Beckmann[1].

Results

Average cement thickness and standard deviation is listed in Figure 3 for all six samples group. Static tensile adhesion test were performed on TT-TT and TT-SB samples and respectively reached an average strength of 19,0±2,0MPa and 13,4±1,7MPa. Static shear adhesion test were performed on TT-TT and TT-SB samples and respectively reached an average strength of 25,5±2,6MPa and 12,8±3,8MPa. Static torsion adhesion test were performed on TT-TT and TT-SB samples and respectively reached an average rotational stiffness of 121,2±11,1Nm/rad and 43,1±18,4Nm/rad (Figure 3). Similar investigation was performed on Trabecular Metal by Beckmann[1], with a tensile strength of 14,9±3,4MPa and a rotational stiffness of 2,8±0,8Nm/rad.

Discussion

Trabecular Titanium^{TM}-on-Trabecular Titanium^{TM} showed higher static tensile, shear and torsion strength respect to Trabecular Titanium^{TM}-on-Sandblasted finishing. Trabecular Titanium^{TM} showed higher tensile strength compared to a predicate porous structure [1] highlighting its potential in clinical use for cement adhesion such as locking mechanism between modular components and cemented application.

References

[1] Beckmann, Mechanical properties of a cemented porous implant interface, Acta Orthopaedica 2014; 85 (5): 531–537

Figures

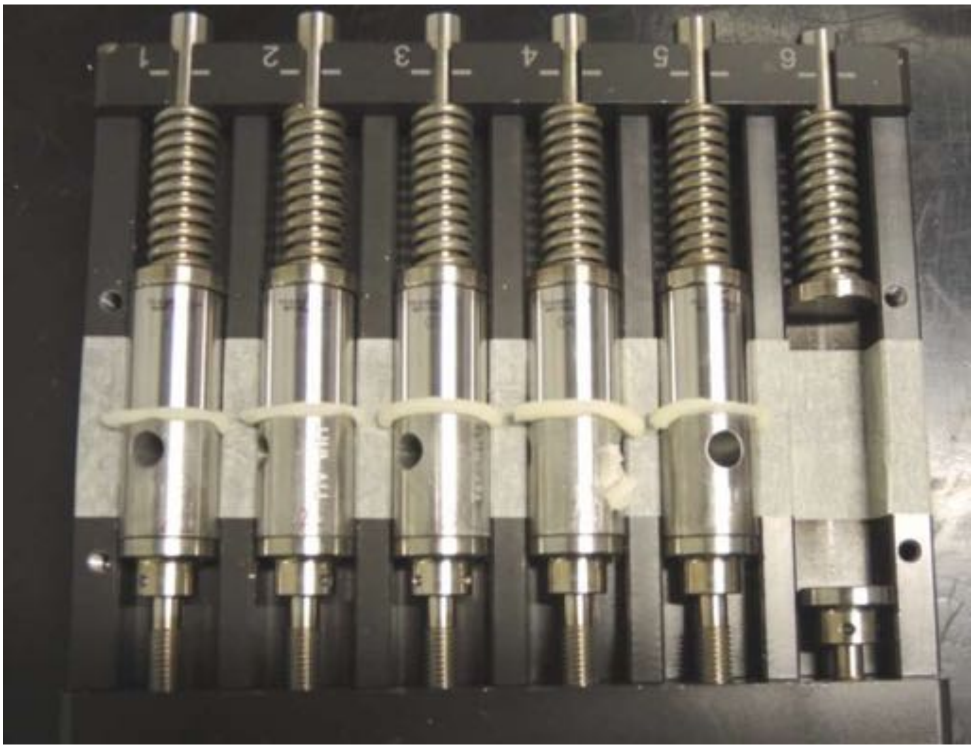

Figure 1

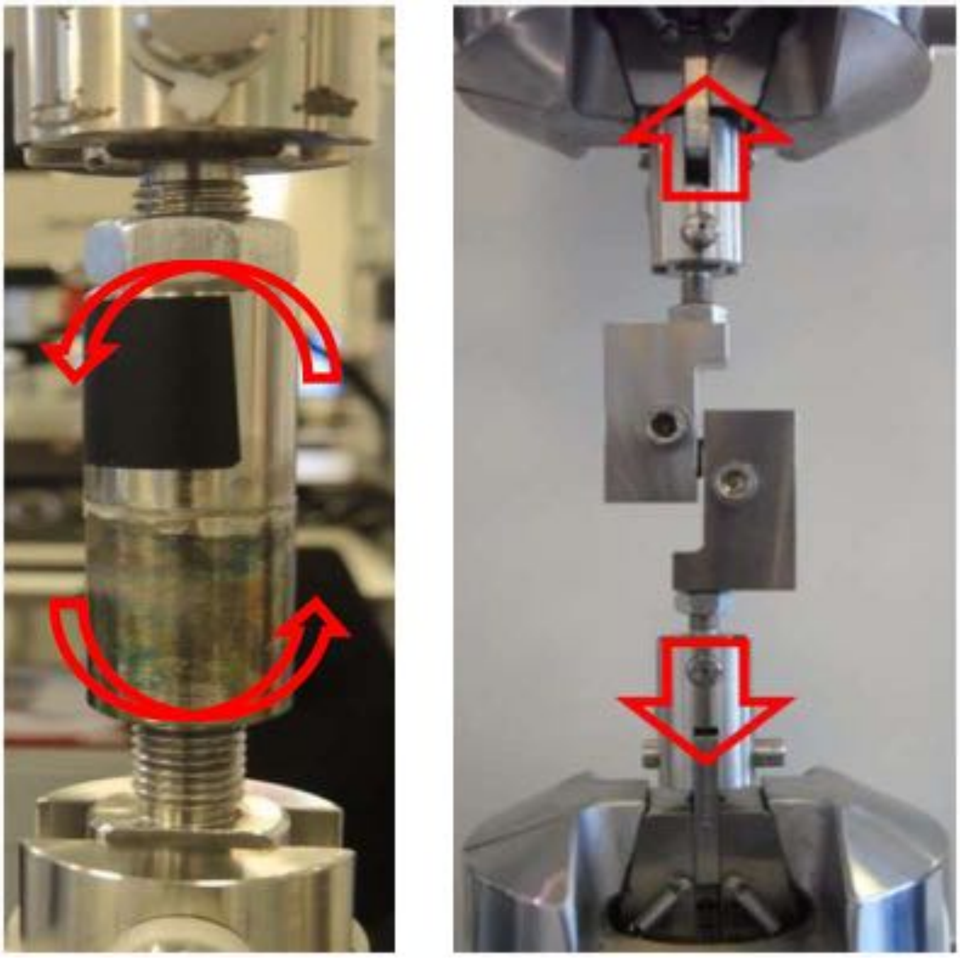

Figure 2

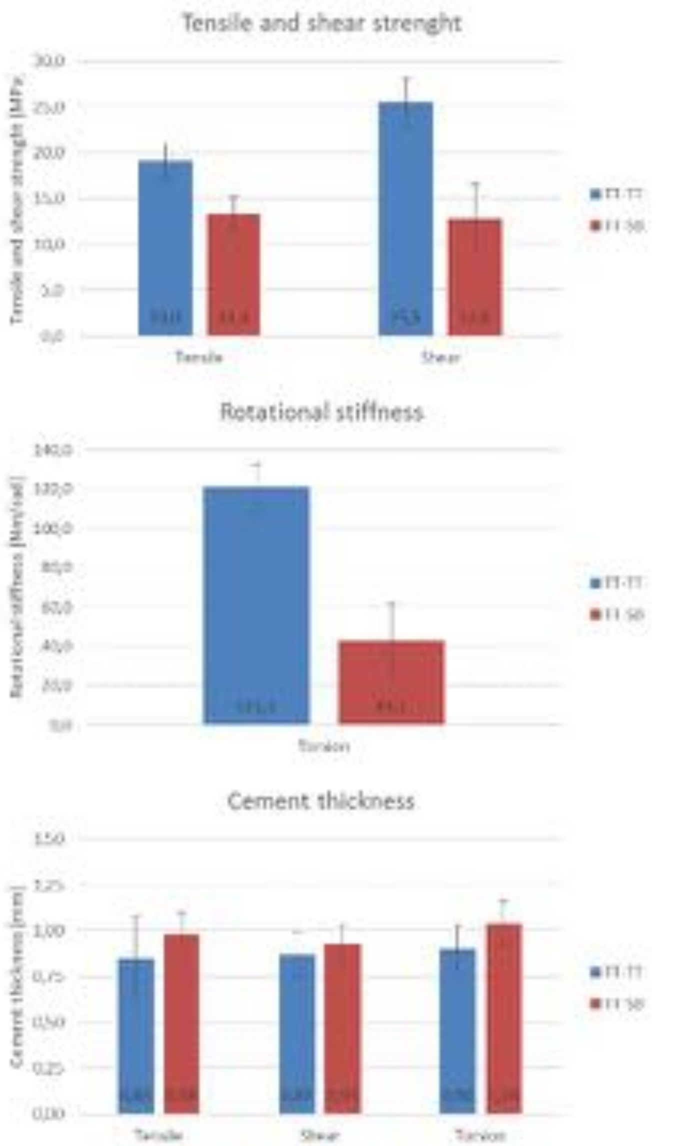
Tensile and shear strenght
Tensile and shear strenght [MPa]
Tensile
Shear
Rotational stiffness
Torsion
Cement thickness
Cement thickness [mm]
Tensile
Shear
Torsion

Figure 3

#6115

Investigation of Architectural and Mechanical Anisotropy in Additively Manufactured Structures With Comparison to Bone

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Additive manufacturing has revealed a new design frontier in orthopaedics. The use of AM manufactured structures such as porous lattices within implants has potential benefits, such as custom mechanical properties, porosity for osseointegration/fluid flow as well as improved fixation features.

Compared to bulk metal properties, it is possible to control the stiffness of a component through adjustable relative density. This is useful due to the influence of load on bone remodelling. The ability to match the stiffness of bone may help reduce problems such as stress shielding, which could contribute to implant loosening.

However, the mechanical properties of bone depend on a number of factors, such as the macro-scale architecture (cortical or trabecular), bone volume fraction and local trabecular architecture, which vary with anatomical location and orientation.

These bone properties are characterised in a number of ways. The star length distribution (SLD) is a statistical measure of the architecture of trabecular bone, which can be calculated from micro-CT reconstructions. The mechanical stiffness and strength are determined from compression testing in different directions.

These measures were applied to two AM structures to compare them to trabecular bone:

- A periodic BCC structure with a 2mm unit cell and 330 µm strut diameter
- A stochastic structure formed by joining pseudo-random points generated using the Poisson-disk method with lines. Struts at an angle lower than 30° to the x-y plane removed to allow for AM manufacturing. 330 µm strut diameter

- Architectural measure, SLD

- 3D models of each structure were analysed to find the star length distribution, a measure of the 'average orientation' of the material within the structure. This was compared to found SLD measurements of bone.

- Mechanical testing

- 10 x 10 x 12 mm specimens were generated in 10 different orientations and compression tested to obtain the mechanical anisotropy of each structure.
- An Instron 8874 with a 10kN load cell was used at an extension rate of 2 mm/min to measure stiffness. This corresponds to a strain rate within the correct limits (ISO 13314:2011(E)). A sampling rate of 30Hz was used. The platens of the machine were lubricated and LVDTs were used to remove any compliance effects.
- Stress-strain curves were obtained and elastic moduli were estimated from a hysteresis loop in the load application, from 70% of the plateau stress to 20% of the plateau stress. The specimen is then fully compressed to a high strain.

Both structures showed a characteristic anisotropy in both the architecture and mechanical stiffness. The BCC structure showed an SLD anisotropy of 6.27 and a mechanical isotropy of 3.92. The stochastic structure showed an SLD anisotropy of 2.81 and a mechanical isotropy of 4.63. The differences between structures may be due to the connectivity in the structure and whether the structure is bend or stretch dominated.

Lattice structures were created which span the range of stiffness found in trabecular to cortical bone, with comparable architectural and mechanical isotropy. Further work would involve greater control of anisotropy in the structure to better match that of bone.

Figures

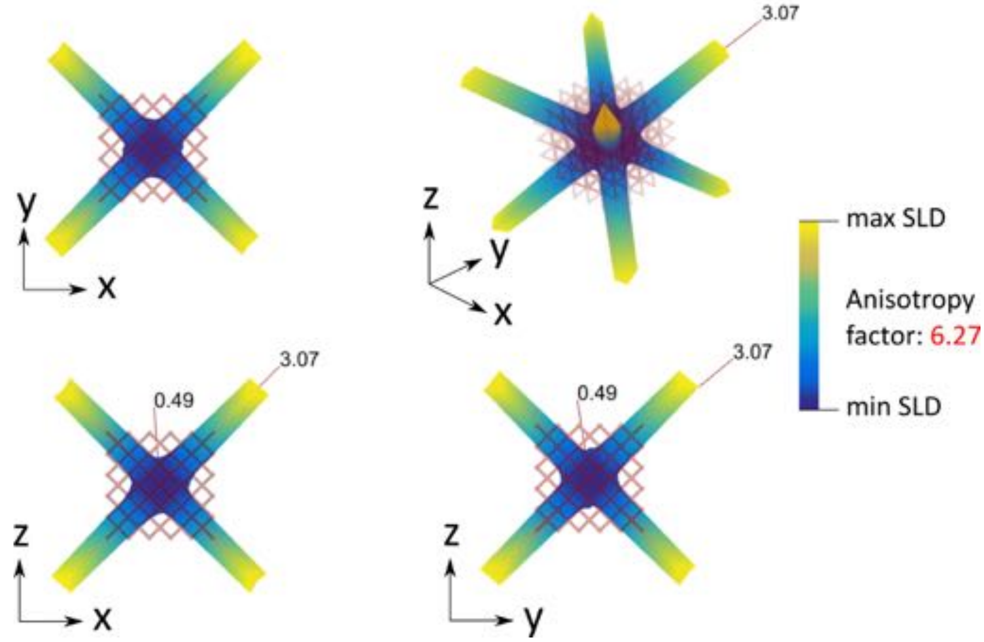


Figure 1

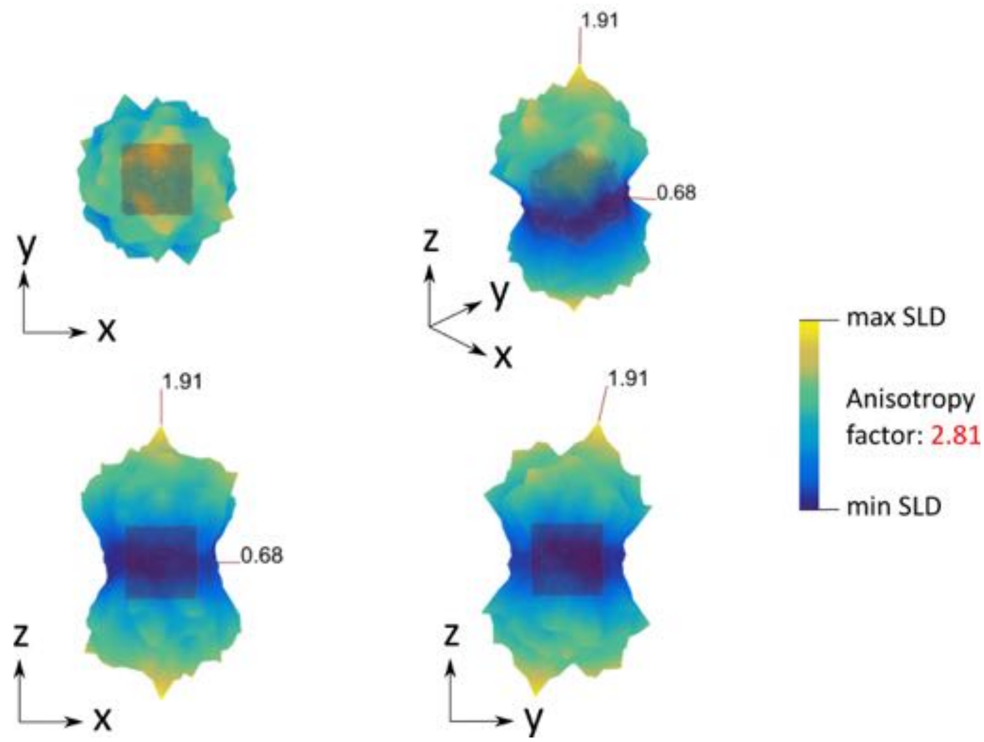
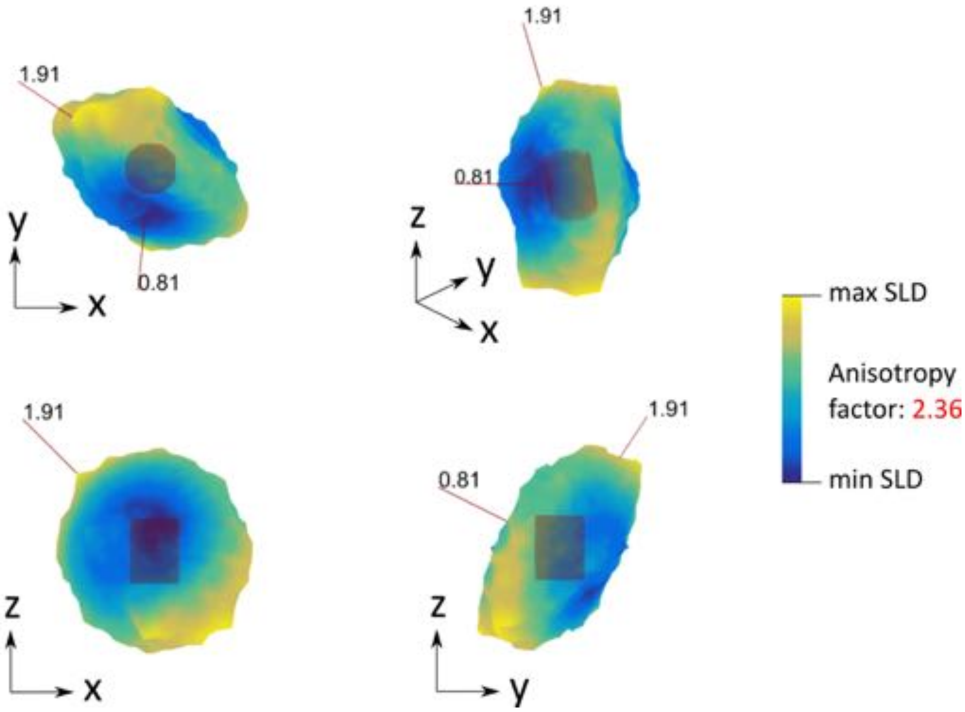


Figure 2


1.91
0.81
y
x
1.91
0.81
z
y
x
max SLD
Anisotropy factor: 2.36
min SLD
1.91
z
x
1.91
0.81
z
y
Figure 3

#5870

Clinical Application of Three Dimensional Printer for Total Hip Arthroplasty With Corrected Femoral Osteotomy

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Background

Corrected femoral osteotomy is needed in total hip arthroplasty (THA) for patients with hip osteoarthritis after Shantz osteotomy because of their femoral deformity. Several complications were reported such as femoral fractures, stem malposition and nonunion. Preoperative planning has to be made in detail to prevent those complications, which can be designed by three dimensional (3D) software. However, implement of the preoperative planning during actual surgery is difficult. We made patient specific guides for osteotomy and reduction by domestic 3D printer to reproduce preoperative 3D planning. We reported the clinical experience of THA with corrected femoral osteotomy by using these patient specific guides.

Case 1

The patient was 75 years-old female. Her left hip was the end-stage of osteoarthritis after Shantz osteotomy and the opposite hip was normal. Bilateral femoral bone models were made on ZedHip (LEXI, Tokyo, Japan). We made planning corrected femoral osteotomy on Magics (Materialise, Leuven, Belgium), and the operative femur after corrected osteotomy was coincided with the mirror image of the opposite femur as ‘the ideal model’. After planning the corrected femur model, we imported this model into ZedHip and made 3D planning of THA using Profemur R (MicroPort Orthopedics Inc., Arlington, USA). We produced the patient specific guides on Magics as follows;

1) A box was overlaid on the posterior surface of the femur and was removed the femoral model (Fig.1a).

2) We made two slits for osteotomy planes and four wire holes to fix the guide on the femur (Fig.1b).

3) The guide was divided into two parts and two wire holes for keeping the reduction position (Fig.1c).

We could decide the location, amount and direction of osteotomy (Fig.2a) and keep reduction easily during operation (Fig.2b). There were no complications. Postoperative femoral model was reproduced with preoperative planning model. The osteotomy portion was united one year postoperatively.

Case 2

The patient was 58 years-old male. Bilateral side of the hip was the end-stage of osteoarthritis after Shantz osteotomy. We planned left THA. The opposite femur could not be utilized as ‘the ideal model’ because of the femoral deformity. Therefore, we used stem implant for adjusting for corrected femoral osteotomy as follows;

1) We decided size of proximal body of Profemur R for the proximal femoral shape on ZedHip, and mobilized the femoral model to fit the distal body of stem.

2) The location and direction of osteotomy was decided on Magics.

3) We made the patient specific guides on Magics and 3D printer as Case 1.

Femoral osteotomy was performed by using osteotomy guide fixed on the femoral surface (Fig.3a), and osteotomy portion was reduced by reduction guide (Fig.3b) before stem insertion.ã€€There were no complications. Postoperative femoral model was reproduced with preoperative planning femoral model. The osteotomy portion was united at 2 years postoperatively.

Conclusion

Patient specific guides for osteotomy and reduction made by domestic 3D printer are new, accurate and inexpensive surgical guides for corrected femoral osteotomy. Further studies for larger number of cases are needed to improve and disseminate this new techniques.

Figures

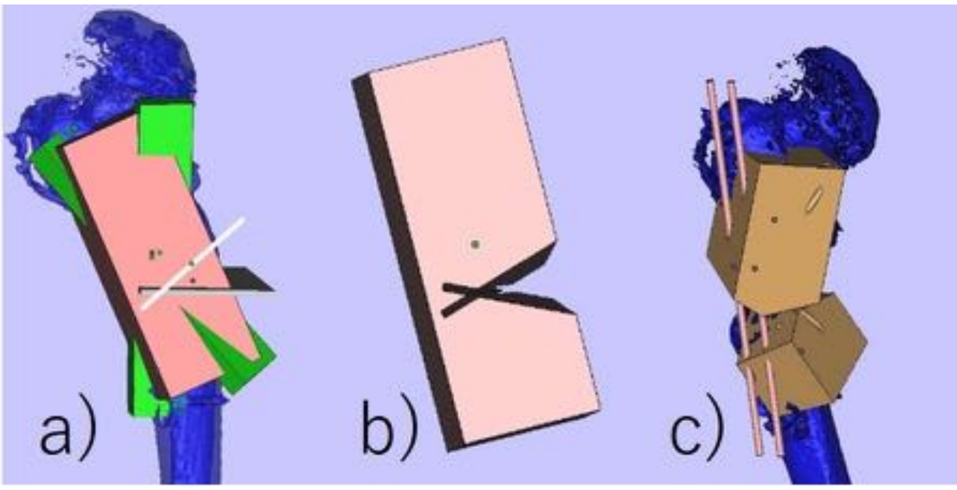

Figure 1

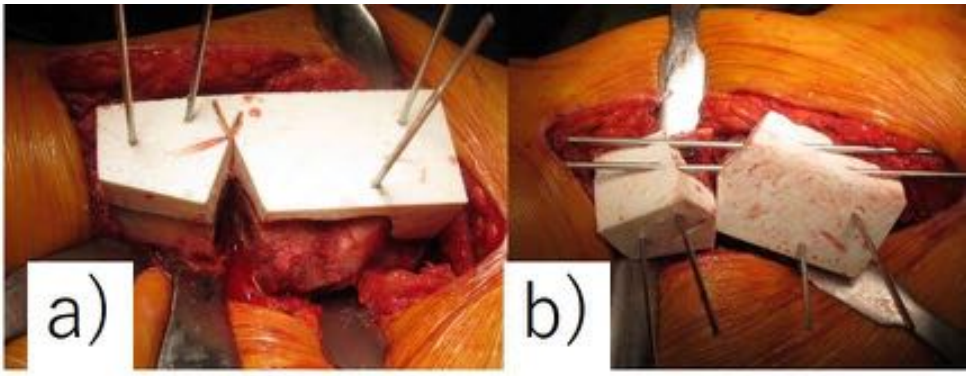

Figure 2

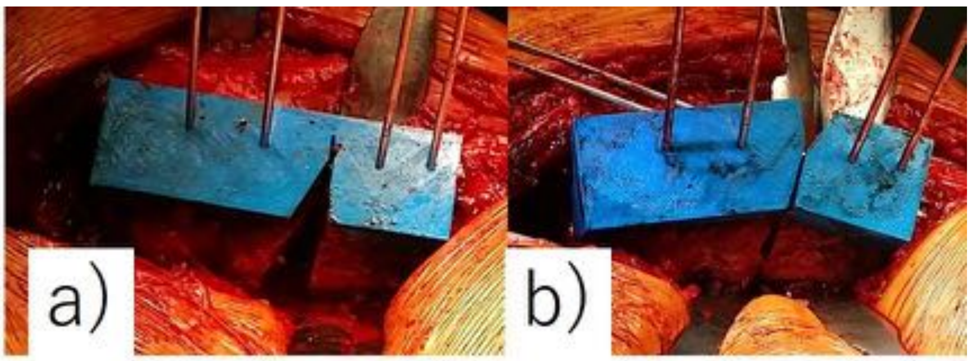

Figure 3

A Comparison of Unit Cells to Optimise Mechanical and Osseointegration Properties in Hip Implants

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Aseptic loosening is the most common cause of failure in load bearing orthopaedic implants. This is most often attributed to stress shielding, which is caused by a mismatch in mechanical properties between the implant and bone, predominantly stiffness. The implant causes a redistribution of the forces through the bone leading to localised tissue resorption in low stress areas and over time loosening of the implant. To address this, the implant design may be modified to introduce porous structures that reduced overall stiffness.

Conventional methods of creating porous structures include the space holder method and gas foaming, although these allow control of the pore size and volume fraction, the position of the voids is random and potentially non-uniform, creating unpredictable mechanical properties. Using additive manufacture predictable porous lattice structures can be built. Two methods for creating lattice structure are explored here: controlled stochastic lattices, and layers of repeating unit cells. Due to the predictable nature of these design methods the mechanical properties can be tailored to suit the needs of the implants. In addition to mechanical optimisation the porous lattice structures can be optimised for osseointegration properties. The ability of the tissue to grow into the implant are affected by; the size of the pores, how interconnected the pores are, the overall void fraction (porosity), the shape and roughness of the pores, and whether the structure is coated.

Although additive manufacture allows great design freedoms, there are also some manufacturing constraints to consider including resolution which is determined by powder and laser spot size, and strut angle since these cannot be too close to horizontal or they will collapse during the build unless supported. This preliminary work uses Finite Element Analysis to model the compressive properties of lattice structures with different design parameters, with the intention to optimise for mechanical, osseointegration and manufacturability properties.

Cylinders of the lattice structures were generated in Simpleware ScanIP (Synopsys, Exeter, UK) and their compression was modelled in Ansys Workbench 18.2 (Canonsburg, PA, USA) in accordance with ISO 13314. Stress distributions for each lattice structure were produced which showed the stochastic lattice did not undergo banded deformation unlike the repeating unit cell based lattices. Future work will physically test the lattices and feed that data back into the model for further optimisation. Other relevant mechanical testing will be modelled and performed in order to choose the optimal lattice design for future implants.

#6133

3D Printed Antimicrobial Silver Titanium Alloys for Arthroplasty

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Introduction

Implant associated infections are responsible for over 10 % of recorded orthopaedic revision surgeries across the UK [1], with higher infection rates commonly observed for other endoprostheses such as cranioplasties [2]. To prevent colonization and biofilm formation on implant surfaces, the use of silver coatings has shown positive results in clinical setting [3] due to its synergistic function with conventional antibiotic prophylaxes [4]. Additive manufacturing allows manufacture of entirely new implant geometries such as lattice structures to enhance osseointegration, however this limits the ability to uniformly coat implants. Direct integration of silver into the powder feedstock for selective laser melting (SLM) may allow manufacture of a biomedical alloy with innate, long lasting antimicrobial properties without compromising possible geometries and with no coating process necessary.

Methods

Feedstock powders of 15-45 micron Grade 5 Ti-64 (Renishaw Plc) and Ag-999 powder (CooksonGold) were characterized using laser particle size analysis, ICP-OES, LECO-ONH, and morphological analysis in SEM. A blend of Ti-64 with 3 wt% Ag-999 powder (Ti-643) was produced by tumble blending, and validated by SEM and EDS. Parameters for manufacture were established using a 17 point design of experiment (DoE) exploring a 2D parameter space of applied laser power and laser scanning speed. Samples were manufactured using a ConceptLaser M2 LaserCusing SLM. Density was assessed by He pycnometry, and cross-sections analysed for defects by optical microscopy. Silver distribution was mapped by micro X-Ray Fluoroscopy (µXRF) and energy-dispersive X-ray spectroscopy (EDS). Optimum parameters were identified and used to manufacture all subsequent samples.

Cylindrical Ti-643 samples were manufactured for further physical characterization and bacterial investigation, alongside control Ti-64 samples manufactured using existing optimum parameters. Samples were tested in as built and polished surface conditions. Contact angle measurements were made by goniometry. Silver elution characteristics were assessed by immersion in water refreshed on a daily basis, and sampled over a 14 day period using ICP-OES. Adhesion and viability of *S. aureus* was compared to control samples using crystal violet staining and live/dead staining with fluorescence microscopy.

Results

Across the entire parameter space tested, selective laser melting (SLM) of all 17 samples was successful, with no delamination. An increased recoater blade speed was required to achieve uniform spreading in process versus pure Ti-6Al-4V powder, indicating an increased cohesivity of the Ti-643 blend. The presence of silver in all samples was confirmed by µXRF, indicating that there was no excessive evaporation of silver in-process. Laser parameters were found to alter the defect density and microstructure scale, though sample density was tightly clustered in a range from 4.415

to 4.453 gcm-3, showing relatively low process variation. Surface condition was found to affect elution characteristics, and bacterial adhesion and viability.

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#6026

Multi-Scale Fabrication of Porous Materials for Engineered Tissue Scaffolds

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The deposition of nanostructured coatings onto microstructured porous templates offers a novel strategy for fabricating bulk materials with controlled architectures at the micro- and nano-scales. Using layer-by-layer assembly, a versatile thin-film fabrication technique, multilayer coatings are deposited onto open-cell foams, resulting in porous materials with highly customizable structure and properties (Figure 1). The compressive mechanical behavior of these materials evolves in a predictable manner that is captured by scaling laws for the mechanical properties of cellular materials. The measured and predicted properties span a remarkable range of density-stiffness space, extending from regions of soft elastomer foams to very stiff, lightweight honeycomb and lattice materials (Figure 2). Biocompatibility is improved by adjusting the surface composition of the coating. On-going and future work is exploring the enormous scope for incorporating tailored degradation, drug delivery, and further biofunctionality by utilising the nanoscale precision over material structure and composition. The ability to tailor structure, properties, and functionality makes this a promising fabrication strategy for engineering tissue scaffold materials.

Figures

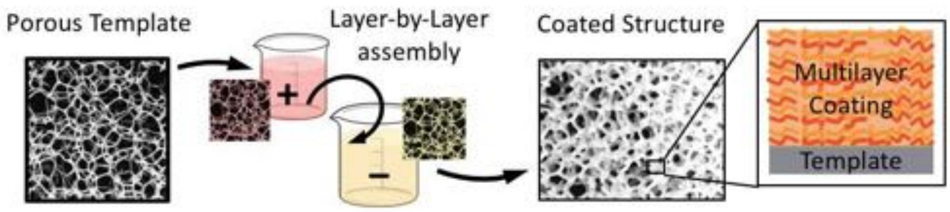
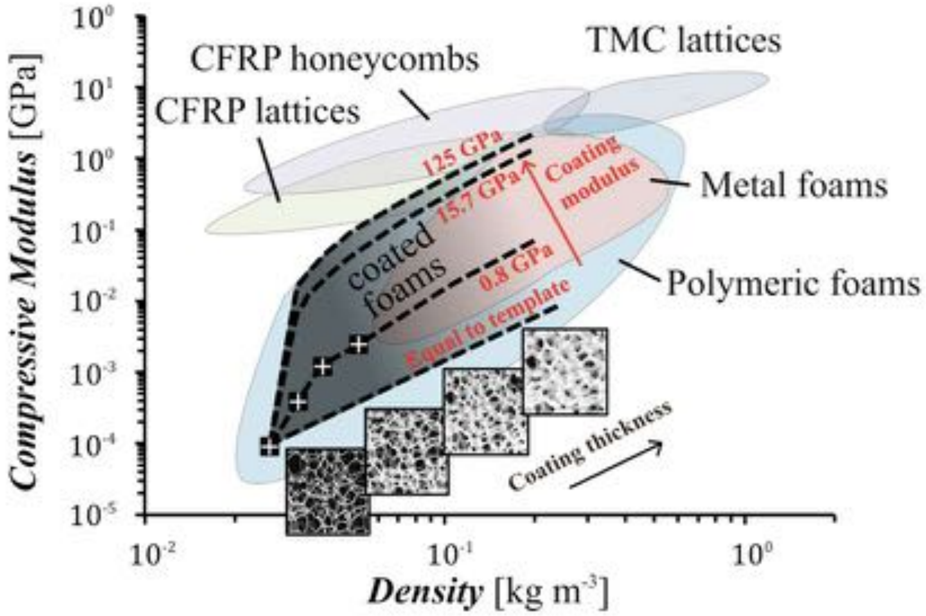


Figure 1



CFRP honeycombs
TMC lattices
CFRP lattices
125 GPa
15.7 GPa
Coating modulus
Metal foams
coated foams
0.8 GPa
Polymeric foams
Equal to template
Coating thickness
Compressive Modulus [GPa]
Density [kg m-3]

Figure 2

#6143

The Future of Biomaterials Science in Orthopaedic Surgery: Innovative Biomaterials for 3D Printing and Tissue Engineering

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3D Printing aims to deliver intricate biomedical devices based upon advanced diagnostic imaging. With the current upsurge in public interest and increasing access to low-cost printers, efforts are underway to produce patient-specific anatomical models, customized implants, and individualized instrumentation. These advances have already proved efficacious. 3D Printing has been used to aid in surgical planning, such as in the development of disposable surgical saw guides and cutting blocks in total knee arthroplasty. These devices may help minimize tissue loss and optimize the native biomechanics of the patient. 3D printed titanium alloys have been shown to be biocompatible with strong mechanical properties for implantation, though bone atrophy and loosening of the implant ultimately occurs with due to stress transfer between the device and bone.

3D printing holds tremendous promise as a scaffold fabrication technique for bone regeneration as it provides a way to mimic the cellular and extracellular structure and components of tissue and bone. This technology also provides precise control of the overall geometry and internal porous structure. The accompanying biomaterials may be successfully embedded within multi-cellular co-cultures and specific growth factors modulated to optimize growth and fixation. There exists a strong impetus to develop a diverse selection of materials that are not only biocompatible and mechanically stable, but also able to maintain cell viability and reinforce native tissue function for use in bioprinting.

This review explores the evolution of 3D Printing technology in the context of biomaterials incorporation. It also aims to critiques the major challenges ahead in optimizing bioinks and biologic performance in bringing 3D bioprinting to clinical practice. More advanced manufacturing techniques of biofabrication, whereby biologically functional products are created through the deposition of bioactive molecules and cell aggregates, are also discussed.

The applications of 3D printing are restricted by the diversity of biomaterials that can be currently implemented. Common materials include metals, bioceramics, synthetics, and natural polymers; each have specific mechanical properties, processing methodology, and cell-material interaction. Biofunctional biomaterials are an emerging class of materials that display adaptability and activity at every phase of bone growth. These biomaterials have been shown to promote osteogenic differentiation, improve calcium phosphate (CaP) precipitation, and regulate osteoblast gene expression. When crafted to emulate the specific micro-environment of bone, bionanomaterials and nanometer polymer-surface modifications accelerate bony ingrowth.

While these materials, which include bioceramics such as hydroxyapatite (HA), calcium phosphate, and bioglass, are osteogenic and promote cell proliferation, they have been shown to lack appropriate mechanical strength. Alternatively, composite scaffolds of HA and tricalcium phosphate and polycaprolactone (PCL)-HA with carbon backbones have been investigated to optimize biocompatibility and architecture to improve the porosity and mechanical strength of these constructs. Furthermore, microscale manipulation of biomaterials allow for integration of antimicrobial properties to combat infection.

Figures

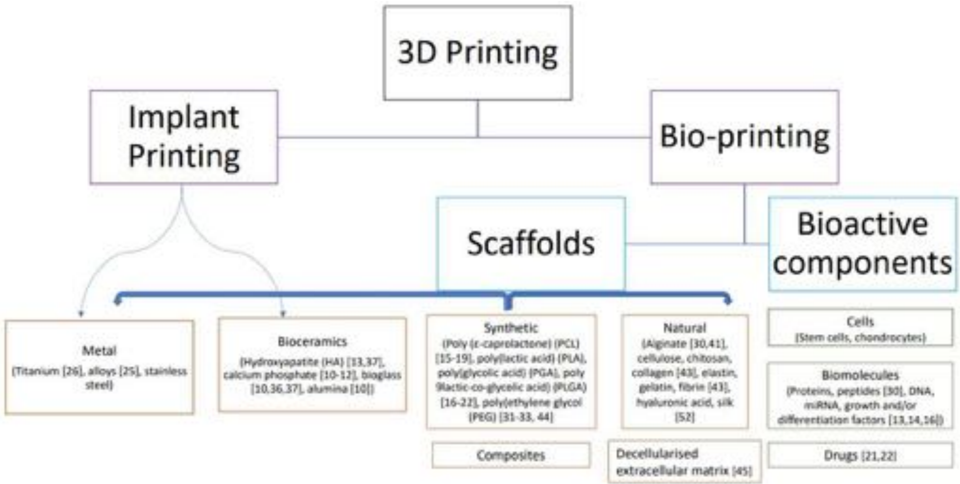

Figure 1

#5709

Surgical Tips of Total Hip Arthroplasty After Transtrochanteric Rotational Osteotomy for Osteonecrosis

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Introduction

The purposes of this study were to investigate the morphologic deformity of the proximal femur and muscle atrophy after transtrochanteric rotational osteotomy (TRO) which affect clinical results of total hip arthroplasty (THA) and to compare them with osteonecrosis of the femoral head (ONFH) which seemed to show normal morphology.

Patients and Methods

From 1998 to 2014, we performed 17 THA in 16 patients after TRO (TRO group). The mean period from TRO to THA was 41 months (14-133), and the mean follow up period after THA was 73 months (29-178). In the same period, we performed 27 THA in 21 patients with ONFH as a control group. All of the patients in both groups received cementless THA through posterior approach. Hip function was evaluated at the latest follow up using hip functions evaluation by the Japanese Orthopedic Association hip score (JOA H-S) and range of hip motion . Surgical time, blood loss and complications were also evaluated. Cup and stem alignment were evaluated with radiographic assessment.

Morphologic deformity of proximal femur and soft tissue thickness were evaluated by reconstructed CT image before THA in both groups. For evaluation of morphologic deformity of proximal femur, the anteroposterior and mediolateral diameters at the 5mm above the minor trochanter were measured respectively. For evaluation of muscle atrophy and soft tissue hypertrophy, thickness of psoas, iliac and gluteus medius muscle, and anterior joint capsule were measured by axial image.

Results

At the latest follow up, there were no differences of JOA scores and range of hip motion in both groups. Surgical time and blood loss were significantly increased in TRO Group compared to control group (205 vs 123 min., 726 vs 370ml, $p<0.01$, unpaired t-test). In femoral component alignment, varus implantation with 3 degrees and more were identified in 3(18%) of 17hips on the radiograph in TRO group, but in 1(4%) of 27hips in control group ($p=0.28$, Fisher's exact test). Posterior dislocation was seen in 4 cases (24 %) in TRO group and 1 case (4%) in control group ($p=0.06$, Fisher's exact test). Ratio of AP/ML diameter of proximal femur was significantly increased in TRO group (1.00 vs. 0.79, $p<0.01$, unpaired t-test). There were no difference in thickness of psoas, iliac and gluteus medius muscle before THA in both groups. Anterior joint capsule thickness was significantly increased in TRO group (10.4 vs. 8.1mm, $p<0.05$, unpaired t-test).

Discussion

Our study showed that THA after TRO is considered a technically demanding surgery because of longer surgical time and greater blood loss, but no significant differences in clinical score or hip motion were found. In THA after TRO, the square shape of the proximal femur causes mislead of orientation of stem insertion point and stem malalignment. Therefore, image intensifier should be used for optimal alignment of femoral component. Anterior bone protrusion of proximal femur and thickness of anterior joint capsule may cause high risk of posterior dislocation by impingement. Therefore, anteriorly protruded bone and thickened capsule should be resected to prevent dislocation of THA after TRO.

Figures

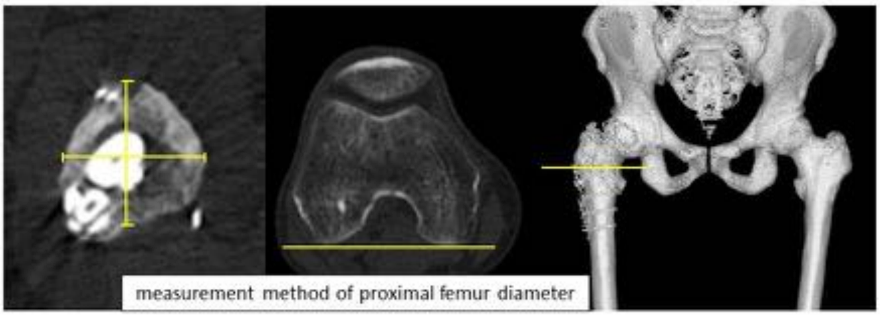

Figure 1

Figure 2

#5989

Encouraging Short Term Outcomes With a Novel Acetabular Reconstruction Construct

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Introduction:

Instability following total hip arthroplasty (THA) is one of the leading causes of early failure of primary THA necessitating revision THA. Despite advances in implant design and surgical technique, instability is one of the most common complications following revision THA with a reported incidence as high as 28%. Cemented dual mobility cups combined with outer porous cups allows for optimal bony purchase by the outer porous metal shell and a more ideal anatomic orientation by the cemented inner dual mobility cup. The purpose of this study is to report on the clinical outcomes of this novel construct.

Methods:

A retrospective review of a single center's revision THA cases from January 1st, 2016 to July 1st, 2017 was conducted. Patients that received this novel construct were included. Demographic data including age, gender, body mass index (BMI), American Anesthesiology Society (ASA) score, smoking history, and calculated Charlson Comorbidity Index (CCI) was collected. Surgical details including reason for revision THA, time in years from primary THA, outer shell size, dual mobility cup size, and additional fixations was collected. Outcome information on radiographic assessment for implant fixation, infections, re-operations, periprosthetic fractures, and dislocations was collected.

Results:

Sixteen patients met the inclusion criteria for the study of which 9 were females and 7 were males. The average age at the time of THA was 61.1 years with an average follow-up of 5.9 months. CCI, ASA, BMI, and smoking history can be found in Table 1. Mean time to revision, reasons for revision, mean outer shell size, mean inner dual cup size, the use of bone allograft, cables/wires, and cages can be found in Table 2. Screws were used for supplemental fixation in all cases.

At the most recent follow-up, there was one patient that required an irrigation and debridement (I&D) for prolonged wound drainage. There were no cases of dislocation or implant loosening at the most recent follow-up.

Discussion and Conclusion:

Our study demonstrates encouraging results with the use of this novel construct in preventing instability after THA as evidenced by the absence of any dislocation or implant loosening. Although this study is limited by the lack of long-term follow-up and sample size, our novel construct shows promising short-term results. Moreover, as the majority of dislocations occur within the first 3 months, we believe that this construct may present as a new technique to solve the challenge of recurrent dislocation and instability following revision THA.

Figures

TABLE 1. Demographics	
Patient Characteristics	**N = 16**
Age y ± SD (range)	61.1 ± 8.8 (20-82)
Sex	
Male n (%)	19 (20.0%)
Female n (%)	75 (80.0%)
BMI kg/m² ± SD (range)	27.9 ± 9.1
ASA score	
II n (%)	76 (80.9%)
III n (%)	10 (10.6%)
CCI	2.75
Smoking status	
Never smoker n (%)	9 (56%)
Former smoker n (%)	4 (25%)
Active smoker n (%)	3 (19%)

Figure 1

TABLE 2. Surgical Information	
Mean time to revision y	18.6 ± 12.8
Mean time to follow up m	5.9 ± 5.2
Reasons for revision THA of interest n (%)	
Aseptic Loosening	8 (50%)
Periprosthetic Fracture	4 (25%)
Conversion from Failed Hip Fracture Fixation	1 (6.25%)
Conversion from Girdlestone	1(6.25%)
Infection	1(6.25%)
Recurrent Instability	1(6.25%)
Mean outer shell size mm	65
Mean dual mobility cup size mm	51.25
Cage n (%)	
Yes	2 (12.5%)
No	14 (87.5%)
Bone allograft n (%)	
Yes	6 (37.5%)
No	10 (62.5%)
Additional plate fixation n (%)	
Yes	2 (12.5%)
No	14 (87.5%)

Figure 2

#5858

Is Rigid Fixation of the Greater Trochanter Necessary for Arthroplasty of Intertrochanteric Fractures?

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Introduction

In this study, the efficacy of a greater trochanter suture technique for fixation of the greater trochanteric fragments in arthroplasty for intertrochanteric hip fractures was investigated.

Materials and Methods

Between 2010 and 2016, a total of 45 patients (1 male, 44 females) with intertrochanteric hip fractures underwent hemiarthroplasty. A total of 47 hips were studied as 1 male and 1 female had both hip fractures. The average age of the patients was 80.6 years (range 65-97 years).

The greater trochanter suture technique was used for fixation of the greater trochanter fragments in 43 cases. There were 4 cases in which the greater trochanter fracture fragments were stable due to soft tissue attachments and no fixation was needed.

All surgical procedures were performed by the same surgeon. The operation was performed by using a modified posterolateral approach of the hip. After implantation of the femoral stem and head prosthesis, the hip capsule was repaired, and the greater trochanter fragments were reduced and fixed by Ethibond No. 2 sutures. K-wires were used for drilling holes on the greater trochanter fragments and the intact femur. Ethibond sutures were passed through the holes and tied tightly by simple sutures. The number of sutures varied from 1 to 3 based on the size and instability of the fracture fragments. After fixation of the greater trochanter, the external rotators were sutured to their insertion sites in a likely manner by additional bone drilling on the greater trochanter with Ethibond No 2. and Vicryl 2-0 sutures passed through the drilled holes.

The minimal follow up of patients was 6 months. Clinical outcomes were analyzed by reviewing the inpatient and outpatient records. Radiologic evaluation was done by examination of greater trochanter union and measurement of migration of the greater trochanter. The measurement of migration of greater trochanter healing was done by comparing the stem-to-tip distance of the post-operative x-ray to that of the latest follow-up x-ray. Functional evaluation was analyzed by assessing change of mobility according to the Koval score.

Results

The mean migration of the greater trochanter of all cases was 5.98 mm. The mean union rate of all cases was 76.6 % (36 out of 47). There was no difference in the ambulation status in 65.2% of patients in all cases, in 69.4 % (25 out of 36) of patients with complete union, and in 54.5 % (6 out of 11) of patients with nonunion. 25.6 % (11 out of 43) had a lower Koval stage by 1 level compared to the pre-injury ambulation status; 9.3 % (4 out of 43) by 2 levels, and 2.3 % (1 out of 43) by 5 levels.

Conclusion

The ethibond suture technique for fixation of the greater trochanter fragments is efficient for fixation of the greater trochanter in patients with arthroplasty for intertrochanteric fractures.

Figures

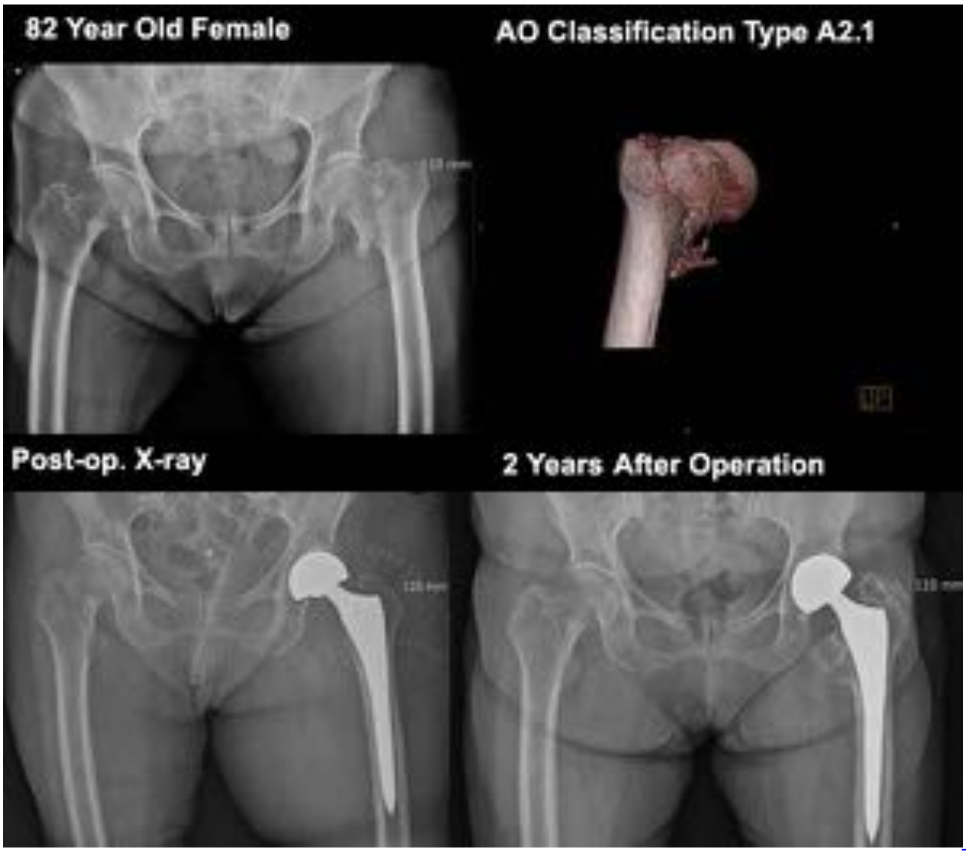

Figure 1

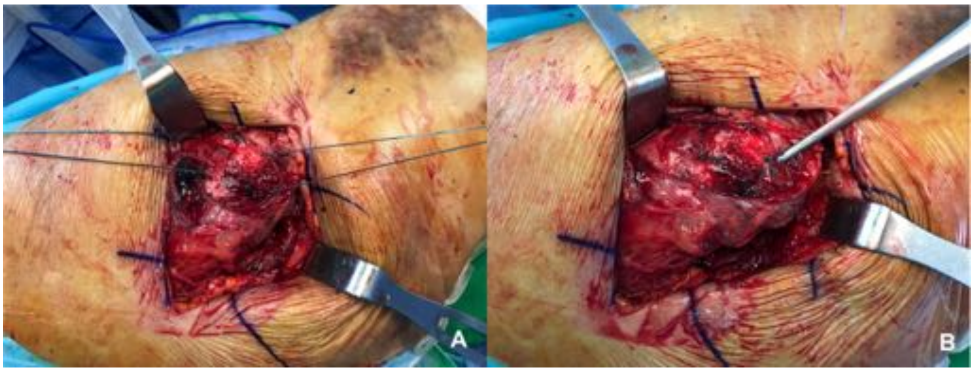

Figure 2

#5616

Short Term Results of Total Hip Arthroplasty With SuperPATH Approach

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Introduction:

Many minimally-invasive approaches have been described in an effort to improve short-term results of total hip arthroplasty (THA), aiming for fast recovery and prevention of dislocation. In our institution, we started to perform THA with SuperPATH approach, including preservation of soft tissue around the hip (James Chow et al. Musculoskelet Med 2011) since July 2014. The purpose of this study is to examine the short-term results of THA using SuperPATH, especially treatment progress of rehabilitation.

Materials and methods:

We performed a study of 30 patients (30 hips) with osteoarthritis of the hip joint who had a THA with SuperPATH approach. There were 4 men and 26 women with an average age of 71 years, which were followed up for 24 months. Patients were clinically assessed with Merle d'Aubigne score, postoperative hip pain during walking by Numerical Rating Scale (NRS:0-10), complications and treatment progress of rehabilitation in regard to moving and activities of daily living. Implant alignment and stability were radiologically evaluated by annual X-ray and CT acquired two months after surgery.

Results:

Merle d'Aubigne score was 10.4 (pain:2.9, mobility:4.5 walking ability:3.0) preoperatively and 16.8(pain:5.9, mobility:5.9, walking ability:5.0) at the latest follow-up. NRS showed less than 3 points for more than 50% of the THA patients next day postoperatively. For more than 80%, NRS showed less than 1 point at 7 days after surgery, and most patients acquired the ability of level ground walking for 100 meters independently by 4 days postoperatively, climbing up and down stairs independently by 5 days and wearing/taking off their socks independently by 7 days. There were no dislocation and infection, but intraoperative proximal femoral fracture was found for two cases, which was managed to treat with additional circulating wire intraoperatively.

From CT images averaged cup position found to be 39±5 degrees for inclination, and 21±6 degrees for anatomic anteversion, averaged stem anteversion to be 33±9 degrees. No loosening of components was evident.

Discussion and Conclusion:

Many minimally-invasive approaches have developed, there have been many reports on fast recovery and low incidence of postoperative hip dislocation, however, the risk of complications related to shortage of operative field has been pointed out. In this study, intraoperative proximal femoral fracture occurred for two cases, but the components position seemed excellent and NRS showed less pain postoperatively and most of the patients acquired walking ability in a few days.

SuperPATH approach, including pass way from between the Gluteus Medius and the piriformis tendon, can preserve the whole short external rotators and capsule of the hip joint, leading to fast rehabilitation progress. Moreover, this approach may be friendly to the surgeons familiar with the posterior approach because of easily conversion to the conventional posterior approach.

#6097

Treatment of Vancouver Type B2 and B3 Periprosthetic Fractures With Revision Total Hip Arthroplasty and Internal Fixation Using Locking Plate.

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Purpose: The purpose of this study is to report results of treatment of Vancouver type B2 and B3 periprosthetic fractures with revision total hip arthroplasty and internal fixation using locking plate.

Material and Methods: This was a retrospective review from January 2017 to March 2018 to identify all revision THA with internal fixation using locking plate performed for Vancouver types B2 and B3 that had a minimum follow-up of six months. Post-operative radiographic was evaluated to assess patient survival, implant failure, and complications.

Results: 6 fractures were included, with an average follow-up 9.5 months. Mean age at the revision surgery was 81.3 years (range, 75–90 years). All fractures were treated with distal fixation modular stem. 5 cases were classified as Vancouver B2 and one case was Vancouver B3. Fracture of great trochanter occurred on one case and resulted in dislocation.

Conclusion: These findings suggest that most cases of type B2 and B3 fracture have been treated successfully with stem revision and open reduction and internal fixation using a locking plate.

#6173

The Lage Maneuver - an Easy, Simple, Reproducible Method to Prevent Scratching of Femoral Head Prosthesis

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Orthopaedic implants, such as femoral heads, sockets and stems, are manufactured with a high degree of smoothness and very low form error in order to function as low wear bearings. The surfaces are subject to both wear and damage during in vivo use. Articulating surfaces naturally wear during normal use. Aseptic loosening associated with osteolysis and release of wear particles is the main reason for revision of total hip arthroplasty (THA). Damage of femoral heads is well known to increase the wear rate at the articulating surface and **is vulnerable to scratching during the maneuver of positioning the femoral component into the acetabulum component** either in primary as in revision total hip arthroplasties. The findings emphasize the importance of achieving and maintaining good surface finish of the femoral head component.

The author presents a very simple and “zero cost” method of preventing scratching of the femoral head of any kind of total hip prosthesis (ceramic on ceramic, ceramic on poly, metal on metal, metal on poly and even metal on ceramic) when the reduction of the femoral head prosthesis is done inside the new acetabular component with metal, ceramic liner or poly liner with metal back (where the scratching can also occur) as one of the final stages of the surgical procedure **which can be crucial to the long survival of the hip prosthesis.**

A short one minute video on an e-poster will show how this can be done being an easy, reproducible, safe and reliable technique to prevent femoral head scratching.

References:

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Wroblewski BM, McCullagh PJ, Siney PD.

#5868

Efficacy of Bone Wax in Total Hip Arthroplasty

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Background

Total hip arthroplasty (THA) is associated with major blood loss and blood transfusion is often required. This study aimed to evaluate the efficacy of bone wax in reducing blood loss and transfusion rates after THA.

Methods

A prospective randomized controlled study that included 100 patients undergoing THA due to Avascular necrosis or Osteoarthritis hip. This study was conducted between March 2016 and March 2017. The bone wax group received 2 g of bone wax, applied onto the cutted proximal femur uncovered bone around the prothesis whereas the control group had hemostasis achieved using electrocautery only. Total blood loss was calculated using the hemoglobin balance method and Hemovac amount.

Results

There were no demographic differences between the 2 groups. The preoperative serum hemoglobin levels were comparable between the 2 groups. The drop in serum hemoglobin levels at 24hr post-operation was mean 1.8 (1.2 ~ 2.3) and mean 2.3 (1.7 ~ 2.6) g/dL in the bone wax and control groups respectively (P = .019), while the drop in serum hemoglobin levels at 48hr post-operation was mean 2.6 (1.6 ~ 3.4) and mean 3.8 (2.7 ~ 4.2) g/dL respectively (P = .013). Total drained Hemovac blood loss at 48hr was 980 and 1230 mL for the bone wax and control groups respectively (P= .017). There was no adverse event associated with the use of bone wax at the 6 month follow-up.

Conclusion

The application of bone wax in THA was safe and effective for reducing total blood loss and maintaining higher hemoglobin levels.

#5735

A Prospective International Multicentre Clinical Trial of Personalised 3D Printed Guides for High Tibial Osteotomy Surgery

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The degree of angular correction achieved in the coronal plane is considered critical to the success of high tibial osteotomy (HTO) surgery[1]. A pilot study reported excellent accuracy using patient specific instruments (PSI) to position drill holes for subsequent plate fixation[2]. However, these guides necessitated a larger than normal incision and dissection. The aim of this study was to determine whether a novel PSI design (Embody, London, UK), which can be used through a standard HTO incision, could deliver an HTO angular correction within 3° of the pre-operative plan in the coronal, sagittal, and axial planes.

Any patient suitable for a HTO was eligible for inclusion. Desired angular correction was determined using standard double-limb weight-bearing anteroposterior radiographs. PSI was designed using a low-dose CT scan of the hip/knee/ankle. A 3 month post-operative CT scan was matched to the pre-operative bone model to determine the difference between the planned and achieved angular corrections. Patient reported outcome scores were collected pre-operatively and at 3, 6, and 12 months post-operatively.

Eighteen HTOs were performed by seven different surgeons at three different expert centres, with PSI successfully used in each case through a standard skin incision. The mean absolute difference between the planned and achieved angular osteotomy correction was not significantly different from 3.0° in the coronal plane (mean difference 2.9° (sd 2.8), p=0.907), but significantly less than 3.0° in the sagittal plane (mean difference 1.5° (sd 1.5), p=0.001), and axial plane (mean difference 1.4° (sd 1.7), p=0.001). There was a strong correlation between the size of the planned coronal angular correction and coronal plane error (r(16)=0.729, p=0.001), with a predicted 0.5^{0} under-correction for each degree of intended correction. Post-operatively there was a significant increase in mean Oxford Knee Score (OKS) at 6 months (8 points, 95% CI 1-15, p=0.032) and 12 months (11 points, 95% CI 3-20, p=0.004)). No significant change in mean EQ-5D-5L score was recorded (p=1.0). There were four complications: two cases of superficial cellulitis, one hinge fracture, and one case of complex regional pain syndrome.

This clinical trial has demonstrated that a novel PSI for HTO, with a small intra-incisional footprint, can deliver a mean angular correction within 3° of the 3D pre-operative plan in all three planes. However, larger coronal plane corrections were associated with increasing under-correction, which needs to be addressed before widespread adoption of this technique can be recommended.

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#5755

Patient Satisfaction, Functional Outcomes and Survivorship in Patients With a Customized Posterior Stabilized Total Knee Replacement

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Background

In this study, we assessed implant survivorship, patient satisfaction, and patient-reported functional outcomes at two years for patients implanted with a customized, posterior stabilized knee replacement system.

Methods

Ninety-three patients (100 knees) with the customized PS TKR were enrolled at two centers. Patients' length of hospitalization and preoperative pain intensity were assessed. At a single time point follow-up, we assessed patient reported outcomes utilizing the KOOS Jr., satisfaction rates, implant survivorship, patients' perception of their knee and their overall preference between the two knees, if they had their contralateral knee replaced with an off-the-shelf (OTS) implant.

Results

At an average of 1.9-years implant survivorship was found to be 100%. From pre-op until time of follow-up, we observed an average decrease of 5.4 on the numeric pain rating scale. Satisfaction rate was found to be high with 90% of patients being satisfied or very satisfied and 88% of patients reporting a "natural" perception of their knee some or all the time. Patients with bilateral implants mostly (12/15) stated that they preferred their customized implant over the standard TKR. The evaluation of KOOS Jr. showed an average score of 90 at the time of the follow up.

Conclusion

Based on our results, we believe that the customized PS implant provides patients with excellent outcomes post-surgery. Moreover, a subset of patients with an OTS implant in one knee and a customized PS implant in the other, we observed a trend in patients preferring the customized PS device over their OTS counterparts.

#6024

A PSI GUIDE for UKR to TKR REVISION

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Introduction & aims

Patient specific instrumentation (PSI) is a useful tool to execute pre-operatively planned surgical cuts and reduce the number of trays in surgery. Debate currently exists around improved accuracy, efficacy and patient outcomes when using PSI cutting guides compared to conventional instruments. Unicompartmental Knee Arthroplasty (UKA) revision to Total Knee Arthroplasty (TKA) represents a complex scenario in which traditional bone landmarks, and patient specific axes that are routinely utilised for component placement may no longer be easily identifiable with either conventional instruments or navigation. PSI guides are uniquely placed to solve this issue by allowing detailed analysis of the patient morphology outside the operating theatre. Here we present a tibia and femur PSI guide for TKA on patients with UKA.

Method

Patients undergoing pre-operative planning received a full leg pass CT scan. Images are then segmented and landmarked to generate a patient specific model of the knee. The surgical cuts are planned according to surgeon preference. PSI guide models are planned to give the desired cut, then 3D printed and provided along with a bone model in surgery. PSI-bone and PSI-UKA contact areas are modified to fit the patient anatomy and allow safe placement and removal.

The PSI-UKA contact area on the tibia is defined across the UKA tibial tray after the insert has been removed. Further contact is planned on the tibial eminence if it can be accurately segmented in the CT and the anterior superior tibia on the contralateral compartment, see example guide in Figure 1. Contact area on the femur is defined on the superior trochlear groove, native condyle, femur centre and femoral UKA component if it can be accurately segmented in the CT.

Surgery was performed with a target of mechanical alignment using OMNI APEX PS implants (Raynham, MA). The guide was planned such that the OMNI cut block could be placed on the securing pins to translate the cut. Component alignment and resections values were calculated by registering the pre-operative bones and component geometries to post-operative CT images.

Results

Four UKA to TKA surgeries have been performed using revision PSI guides. The maximum difference from planned to achieved component alignments are: Femoral valgus = 2.4â°, Tibial varus = 2.5â°, Femoral internal rotation = 3.6â°, Femoral flexion = 5.1â° and tibial slope = 2.9â°, see boxplot of results in Figure 2. All median values are within 2.5â° of the planned alignment. A further five cases are to be analysed.

Conclusions

A PSI guide designed for UKR to TKR revision surgery has been successfully used in surgery with acceptable errors. A larger study must be performed to determine the reliability and reproducibility of the design and method over a wide range of patient anatomy and UKA imaging flare.

Figures

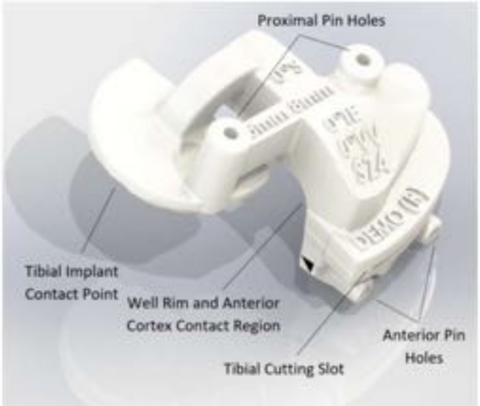

Figure 1 An example of a tibia UKA to TKA PSI guide. The large tibial tray contact plate can be seen on the left.

Figure 1

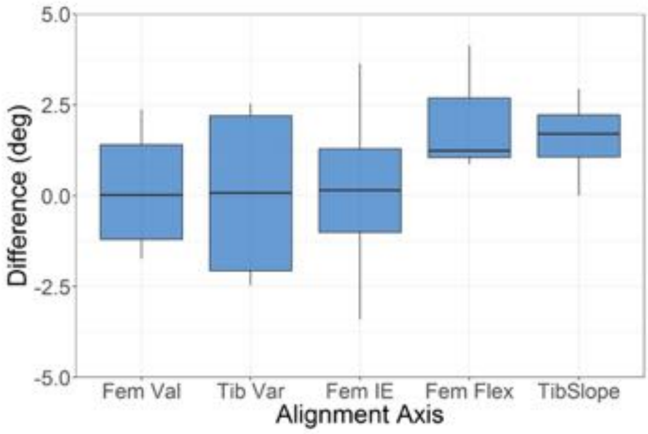

Figure 2 Box plot of the difference between the planned PSI alignment and the post-operatively analysed achieved alignment. All median errors are within 2.5^{o} of planned.

Figure 2

#5795

A Prospective Study of Patient-Specific Total Knee Arthroplasty Compared to an Off-the-Shelf Design:

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Background/Purpose: Patient-specific design (PSD) total knee arthroplasty (TKA) implants are marketed to restore neutral mechanical axis alignment (MAA) and provide better anatomic fit compared to standard off-the-shelf (OTS) TKA designs. The purpose of this study was to compare the Knee-Society scores, radiographic outcomes, and complications of PSD and OTS implants.

Methods: IRB approved prospective study comparing PSD and OTS by a single surgeon. Implant design change in PSD occurred during the study leading to PSD-1 and PSD-2 subgroups. Demographic, radiographic data including MAA, coronal-tibial angle (CTA), femoro-tibial angle (FTA), tibial-slope (TS) and patella-tilt (PT), and complications were analyzed. Minimum follow-up was 2 year or until revision, and patients completed Knee-Society scores preoperatively, and postoperatively at 3-, 6-, 12-, 24 weeks and final follow up.

Results: 136 patients (154 knees), average age (62.7 ± 8.4 years) and follow up (3.1 ± 1.5 years). PSD-1 (77 knees), PSD-2 (36 knees), and OTS (41 knees). PSD-2 had significantly higher early Knee-Society function scores compared to PSD-1 and OTS up to 6 months. All groups had excellent knee society scores after 6 months. PSD-2 had significantly shorter hospital stay ($p<0.001$), and less hemoglobin drop ($p = 0.031$) compared to PSD-1 and OTS. No significant difference in MAA ($p=0.349$) or final ROM ($p=0.629$). There was approximately 1 degree difference between the groups in the CTA, FTA, TS and PT. Failures requiring revision were 24% (18/75) PSD-1, 0% PSD-2, and 3% (1/35) OTS. Most common modes-of-failure were tibial subsidence (56%) and polyethylene locking mechanism failure (22%) in PSD-1.

Conclusion: PSD-2 had better early Knee-Society function scores, shorter hospital stay, lower hemoglobin drop, and no failures compared to PSD-1 and OTS. There was an unexpected high failure rate in the early patient-specific design TKA that was not seen after the manufacturer changed the design.

#6170

Can 3D Guides Improve Rotational Alignment in Megaprosthesis Surgery?

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Introduction

Rotational or axial alignment is an important concept in total knee surgery. Malrotation of the femoral component can lead to patellofemoral maltracking, pain and stifness. In megaprosthesis surgery of the knee, achievement of correct rotation is even more difficult because of the lack of anatomical landmarks. The linea aspera is often the only remaining landmark, but its reliability is questionable. However, studies concerning this problem are lacking.

Goal of research: Can custom-made 3D-guides help with rotational alignment of the knee after a wide resection of the distal femur?

Material and methods

Custom-made 3D-guides were designed from CT-scans, with the help off Mimics and 3-matic (Materialize NV, Leuven, Belgium) and SolidWorks (SolidWorks Corp., Massachusetts, USA). Anterior was defined as 90° relative to the PCL, with the center of the best-fitting inner circle as rotation point (Fig. 1). Firstly, the accuracy of the 3D guides were tested. Twelve 3D guides, on different heights, were made for 3 cadaveric femora. Anterior was marked with a pin and the position was evaluated with CT-scan (Fig. 2). Secondly, to mimic surgery, seven megaprosthesis were placed in 4 cadavers, using the 3D-guide to indicate anterior and cutting surface (Fig. 3). Resection height was aimed at 13cm. The position of the megaprostheses were also evaluated using CT-scan.

Results

The pins deviated on average 0.65° (SE: 0.75°) from anterior. Only 2 pins deviated more than 1° (1.5° and 2.6°). The resection height indicated by the 3D-guide was on average 2.4mm (SD: 0.7mm) to high.

The 7 megaprosthesis deviated on average 3.1° from anterior, with 4 prostheses deviating more than 1°. The 2 prostheses in endorotation were placed more lateral then was planned, while the 2 in exorotation were placed more medial.

Discussion

The 3D-guides were reliable in indicating anterior and the resection height, but valgus/varus was inadequately controlled. Furthermore, the 3D-guides did not take into account that centering of the prosthesis could be a problem. When the prosthesis was place more medial or more lateral the rotation point was changed and if the prosthesis was aligned with the previously indicated anterior it was placed respectively in exorotation or endorotation (Fig. 4: prosthesis placed to medial, which resulted in exorotation of the implant).

Conclusion

A 3D-guide designed to guide alignment in only one plane, like in this study, is not helpful in a complex surgery like the placement of a megaprosthesis. When 3D-guides are designed to help with the alignment of megaprostheses it should guide alignment in all planes (axial, frontal, saggital) and help with centering of the implant.

Future research: will aim to develop costum-made 3D guides, to guide alignment on all planes, and improve centering of the femoral component. Repercussion on function and kinematics will be evaluated with knee simulator testing and CT-scan.

Figures

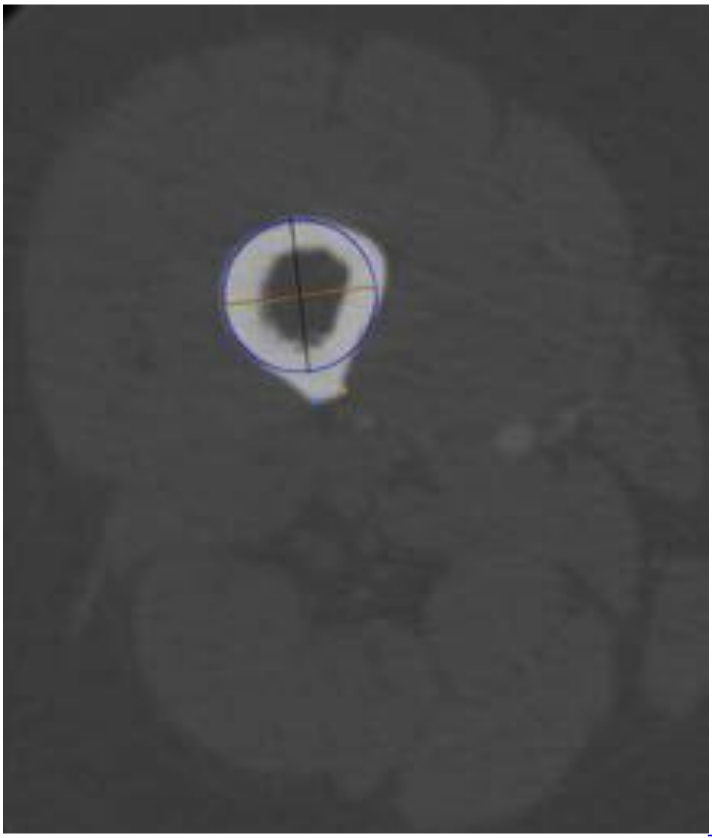

Figure 1

Figure 2

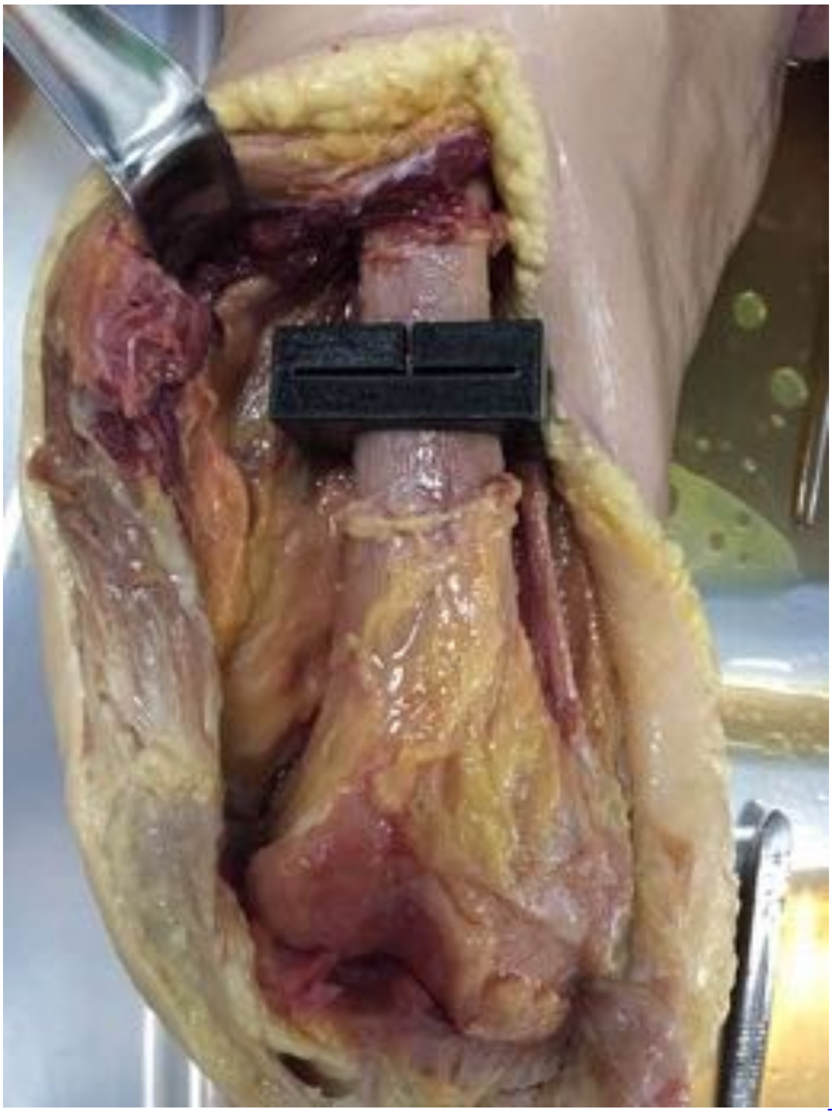

Figure 3

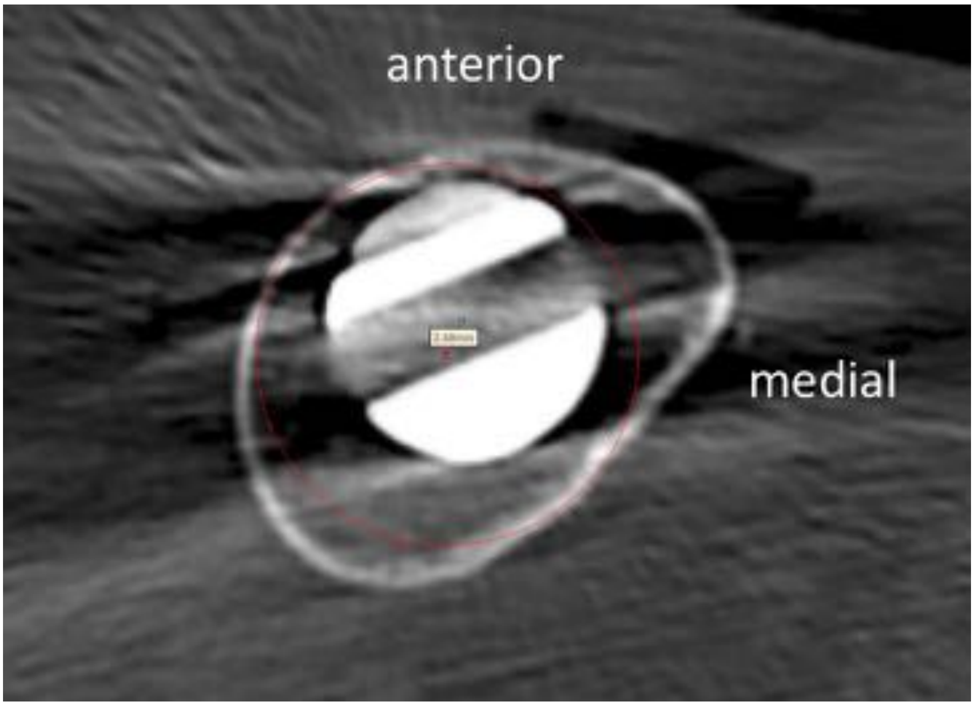

Figure 4

#6156

Effect of Different Depth Designs of 3D Printed Patient Specific Instrument (PSI) on Planar Cutting Operation Accuracy in Simulated Orthopaedic Surgery: A Preliminary Study

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Introduction:

The cutting accuracy of 3D printed PSI is vital in joint-preserving surgery while the investigation of cutting accuracy of PSI is still lacking. The hypothesis is that the depth of the blade-guiding slot of PSI is the primary factor in operation accuracy. Thus, the present preliminary study compared the cutting accuracy of PSIs with cutting guides at different depths.

Methods and Materials:

Each group has 4 PSIs at different depths: 15mm, 25mm, 35mm and 45mm. The cutting angles of PSIs are all different. 7 groups of PCF30 Sawbones blocks were cut by 3 surgeons (3 groups; 3 groups; 1 group) with the use of an oscillating saw which is equipped with a sagittal blade, enough water was used for cooling and lubricant. Each block was scanned three times by a 3D scanner: bare block, mounted with a PSI and after cutting. Two criteria were assessed using MATLAB: (1) the error angle between the target cutting plane and the cutting surface; (2) the flatness of the cutting surface.

Results:

The mean error angles for 15mm/25mm/35mm/45mm depth were 1.09±0.9°, 0.97±0.43°, 0.82±0.4°, 0.85±0.27° respectively. There was no significant difference across all the 7 groups ($P = 0.58$). However, 5 groups (Figure 1) illustrated downhill trend of error angles with the increase of depth ($P = 0.03$), whereas the other 2 groups from the same surgeon had uphill trend. For the other two surgeons, depths helped to decrease the error angles (correlations: -0.35 and -0.37). The longitudinal inclinations of PSIs slightly increased the error angles (correlation: 0.17) while the transversal inclinations slightly decreased the error angles (correlation: -0.16).

The flatness deviations (ISO 12781-1:2011) were divided with a 0.02mm interval from 0mm to 1.5mm, the area percentages of all intervals on each cutting plane were calculated along with the accumulations of the percentages, the deviation at 90% was chosen as flatness criterion. The uneven planes (15mm: flatness > 0.2mm; 25mm: flatness > 0.14mm; 35mm: flatness > 0.13mm; 45mm: flatness > 0.19mm) were visualized for retrieving the cutting process (Figure 2), it was found that 90% of areas had flatness as 0.08±0.01mm without the outliers. There was no significant difference of flatness at different depths ($P = 0.5$). The longitudinal inclinations of PSIs hardly influenced the flatness (correlation: -0.06) while the transversal inclinations slightly decreased the flatness (correlation: 0.17).

Discussion:

The lowest error angles happened at 35mm although the values were close to those at 45mm. This indicates the 45mm PSIs were easier to be bent so that the guidance was impaired. Different surgeons might be used to different designs since two surgeons benefited from longer guides while another one gained opposite effect. The flatness visualisation method can be extended as a surgical skill assessment tool.

Conclusion:

This study seems to confirm a decrease in error angles with the increase of depths, no improvements on flatness. Better ergonomics (appropriate inclinations) improves accuracy. The strength of PSI affects the accuracy, potentially the expertise of surgeons as well. This preliminary study would help to build the power study.

Figures

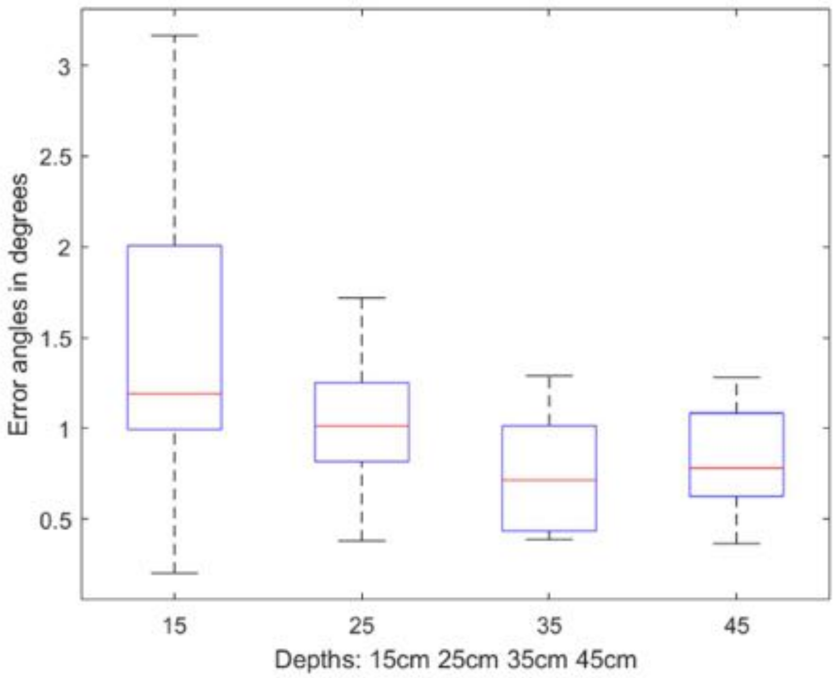

Figure 1: Error angles of the 5 groups with downhill trend

Figure 1

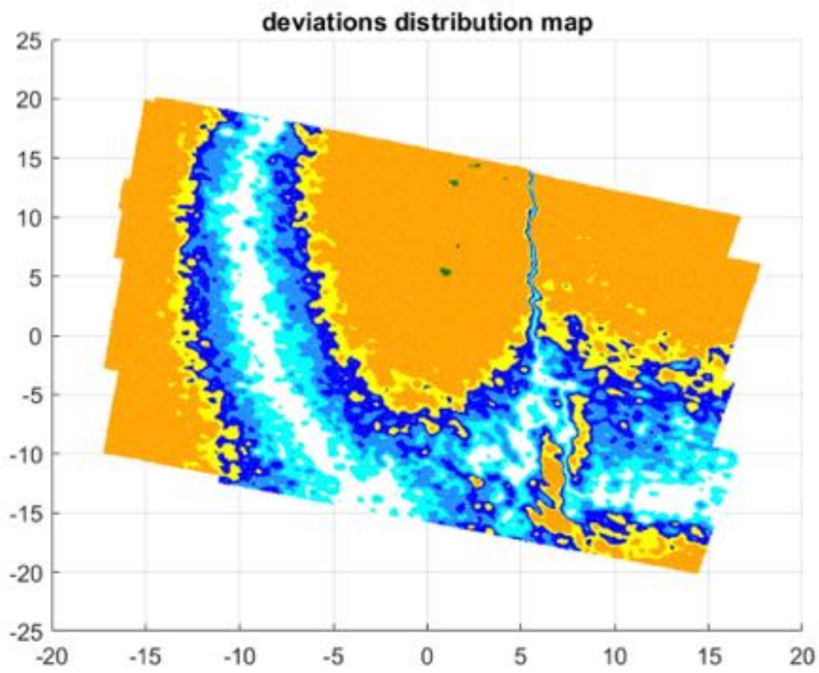

Figure 2: Reconstruction of one uneven cutting plane: white:0-0.02mm; cyan:0.02-0.04mm; dodgerblue:0.04-0.06mm; yellow:0.08-0.1mm; orange:0.1-0.26mm; green:0.26-0.5mm. The majority of this plane is between 0.1-0.26mm which is significantly higher than the average value. It also indicates the surgeon cut the block from different directions with multiple attempts.

Figure 2

#5498

Accuracy of Alignment Determined by Patient-Specific Instrument in Total Knee Arthroplasty

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Purpose: The purpose of this study is to assess accuracy of alignment determined by patient specific instrument (PSI) in total knee arthroplasty (TKA)

Materials and methods: From June 2017 to December 2017, twenty seven TKAs using PSI were enrolled PSI for TKA was manufactured by home production of author's institution and registered in Korea ministry of food and drug safety(Fig. 1). The accuracy of intraoperative alignment determined by the patient-specific guide were recorded using imageless navigation. Data recorded included coronal alignment, posterior slope, femoral sagittal alignment and clinical transepicondylar axis. An acceptable result was considered an error within ±3° in each planes.

Results: In tibial coronal plane, the mean deviation from expected alignment was 1.4°±1.7° (range -2° to 5°). Positive value indicate a varus alignment from the expected alignment and negative values a valgus alignment. In tibial sagittal plane, the mean deviation from 3° of posterior slop was 2.1°±2.2° (range -2° to 8°). Positive values indicate a more posterior slope from the expected alignment and negative values a more anterior slope. In femoral coronal plane, the mean deviation from expected alignment was 0.9°±2.0° (range -3° to 5°). Positive value indicate a varus alignment from the expected alignment and negative values a valgus alignment. In femoral sagittal plane, the mean deviation from the expected alignment was 1.2°±2.3° (range -3° to 6°). Positive values indicate a flexion from the expected alignment and negative values an extension. In clinical transepicondylar axis, the mean deviation from the expected alignment was 0.0±2.3 (range -4° to 3°). Positive values indicate a more external rotation from the expected alignment and negative values an internal rotation. On the tibia, acceptable alignment were obtained for measurements 25 (92.6%) in the coronal plane and 21 (77.8%) in the sagittal plane. On the femur, satisfactory alignment were obtained for measurements 24 (88.1%) in the coronal plane and 23 (85.2%) in the sagittal plane. In clinical transepicondylar axis, satisfactory alignment were obtained for measurements 24 (88.1%).

Conclusion

PSI does not appear to provide the outstanding advantages in restoring alignments. However, TKA with PSI could be used as an alternative to conventional TKA with caution for sagittal alignment of the tibia. More experience and precise pre-operative plan preparation is required to improve the accuracy of sagittal alignment of tibia.

Figures

Figure 1

#5786

Total Knee Artrhoplasty With PSI Tecnique, Our Experience With 82 Cases

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Introduction: the medial pivot total knee arthroplasty (TKA) aims to reproduce the normal knee kinematics and biomechanics with high medial stability and unconstraining lateral compartment. Patients specific instrumentation (PSI) provides a preoperative planning with 3D bone model on which engineers plan the position and size of prostheses components to achieve the best limb alignment and implant positioning. Then, the surgeon is able to modify the programme or validate it. This study's goal is to evaluate if CT-based PSI is effective on restoring lower limb alignment and providing good clinical outcomes.

Materials and methods: we retrospectively examined 82 medial pivot TKA implanted with CT-based PSI technique between Jan 14 – Dec 16. Postoperative X-rays were evaluated to study the femoral and tibial component 2D radiological alignment, while Hip-Knee-Ankle Angle (HKA) was evaluated preoperative and at 12 months postoperative. Furthermore, we examined the distribution of the sizes of the implants, the accordance between the planned sizes and the sizes actually implanted and the tibial insert thickness distribution. Clinical outcomes were evaluated with Knee Society Score (KSS) preoperative and 6 months postoperative.

Results: the average age of patients resulted 70,5 years. Our preoperative mean HKA was 176,9°, the postoperative HKA at 12 months resulted 177,6°, showing a good recovery of lower limb alignment. The KSS improved from 61.5 points preoperative to 194 points at 6 months postoperative. The most common femoral sizes implanted (72,6%) were sizes 2-3-4; concordance between the planned and implanted femoral sizes was 84,2%. 73% of tibial implants were of size 2-3-4; we registered no difference between planned and implanted tibial size on 81,7 % of patients. The thinnest tibial insert (10 mm) was implanted on 57,7% of patients, 11 and 12mm insert was implanted on 25,6% of the knees.

Conclusions: our results confirm that medial pivot TKA can offer excellent clinical outcome, as this kind of implant mimic the normal knee kinematics and biomechanics. PSI technique can help in difficult cases to obtain lower limb alignment and provides a good accordance between planned and implanted sizes. Nonetheless literature confirms that PSI technique is money and time saving. Mismatching between planned and implanted sizes may be related to a lack of recognition of osteophytes during the preoperative study. Soft tissue balance that, for now, can't be defined preoperatively may be adjusted intraoperative both with the thickness of tibial insert and rotation of the femoral component.

Tibial Alignment Using an Extramedullary Guide That the Amount of Distal Rod Shift Was Decided at Pre-Surgical 3-D Planning in Total Knee Arthroplasty

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Background: In total knee arthroplasty (TKA), alignment of the tibial component affects durability and function.

Objectives: Tibial osteotomy was performed using an extramedullary guide that the amount of distal rod shift was decided at pre-surgical planning. Planning was done on 3D-CT templating software. Alignment of the tibial component was examined.

Design and methods: Forty-three patients (53 knees: 3male, 50 female)underwent TKA in which a conventional extramedullary guide was used with a predetermined method. The patients' mean age was 74.2 years, and the diagnosis was osteoarthritis in 23 cases and rheumatoid arthritis in 8 cases. The mean body mass index (BMI) was 26.1 (SD 4.8) kg/m^2. A conventional extramedullary guide that can slide a proximal spike arm and hold the medial-lateral side of the distal lower thigh tightly was used. On 3D-CT templating software, the level position of the distal clamp of the guide was placed 4 cm proximal from the projection of the medial malleolus of the ankle. The transverse diameter at that level of leg soft tissue was measured, and the mid-point of that diameter was determined. The difference between that mid-point and the tibial mechanical axis was measured (Distal medio-lateral offset :DMLOS)[Fig.1]. The distal rod of the extramedullary guide was shifted by this difference. In profile [Fig.2], the proximal spike arm distance (Proximal offset :POS) and the distance between the distal front skin contact region and the rod (Distal offset :DOS) were measured; these were used for the tibial slope angle in the pre-surgical plan**.** At surgery, the extramedullary guide was set as during planning, and the osteotomy was performed. After surgery, full-leg CT was obtained, and alignment of the tibial component was measured by 3D-CT templating software.

Results

In the coronal plane, the mean alignment error of the tibial component was 0.1° (SD 1.0°). The mean absolute value of the error was 0.6° varus (SD 0.7°). Coronal plane error less than 3° was seen in 98.1% of cases. In the profile plane, the mean alignment error of the tibial component was 0.4° posterior slope (SD 1.4°) to the target angle. The mean absolute value of the error was 1.1° (SD 1.0°). Profile plane error less than 3° was seen in 98.1% of cases. There was no significant correlation between the error value and BMI in either the coronal or the profile plane.

Conclusion: The extramedullary guide method that the position of the distal rod of the guide was decided at pre-operative planning with 3D-CT showed adequate accuracy.

This method can be used using a conventional guide and can reduce adjustment during surgery.

Figures

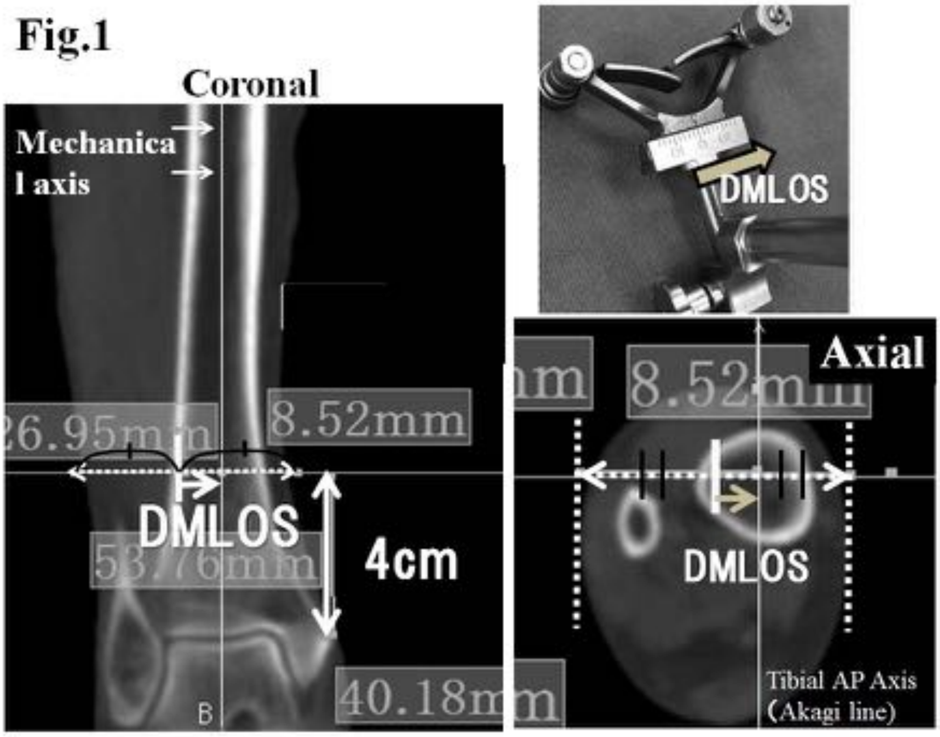

Figure 1

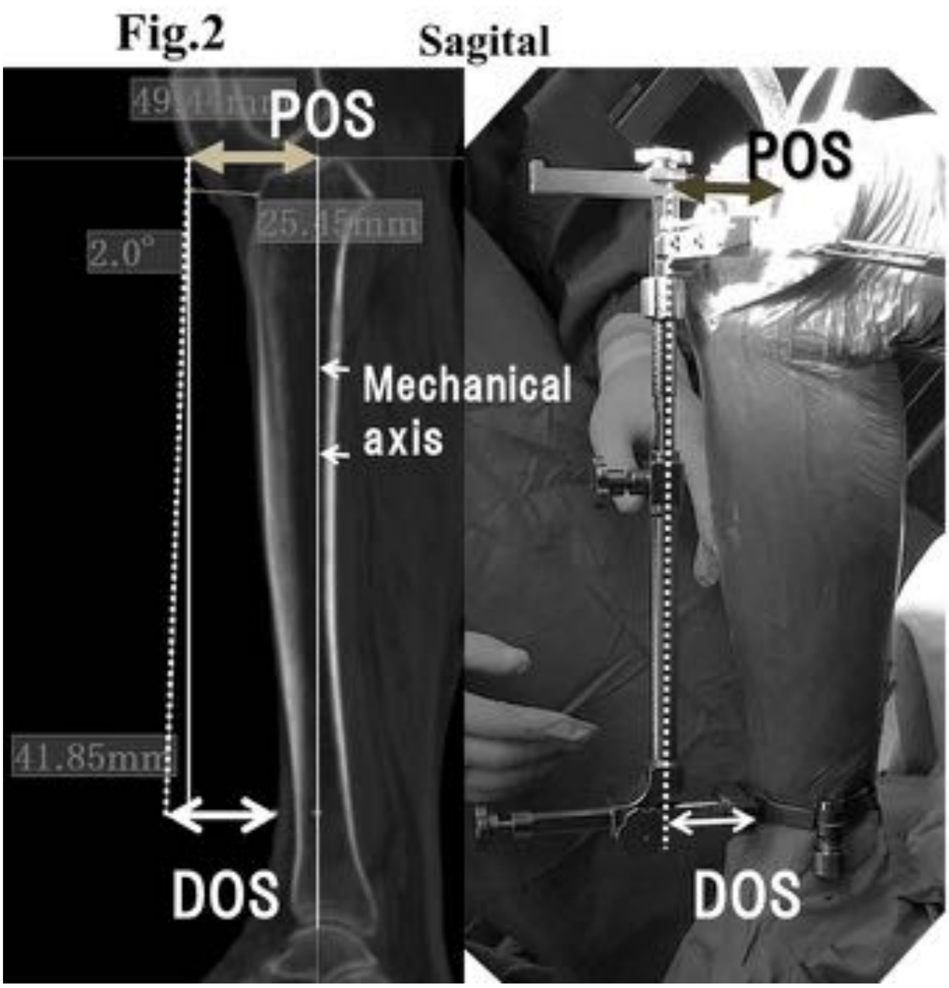

Figure 2

#6197

Accuracy of Accelerometer-Based Portable Navigation System and CT-Based Patient Matched Instruments in Total Knee Arthroplasty

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INTRODUCTION

Accelerometer-based portable navigation system (KneeAlign2, OrthAlign Inc., Aliso Viejo, CA) and CT-based patient matched instruments (PMI, Teijin-Nakashima medical Co., Ltd. Tokyo, Japan) are expected to improve mechanical axis and component alignment compared to conventional instrumentation in total knee arthroplasty (TKA). However, the accuracy was evaluated by only radiographic measurements in the past reports. The purpose of this study was to compare the accuracy of these technologies with radiographic and three-dimentional (3D) CT evaluation.

METHODS

Sixty nine consecutive patients (77knees) with severe osteoarthritis underwent a primary TKA using the KA2 system or PMI. The cemented, fixed-bearing, cruciate-retaining prosthesis were implanted in all patients. We used a radiographic evaluation consisted in long-standing radiographs postoperatively to measure the hip-knee-ankle angle (HKA), frontal femoral component angle (FFC), frontal tibial component angle (FTC). The 3D-component positioning were analyzed more precisely with 3D matching bone model made than pre- and postoperative CT images. In the same coordinate axis, the component positioning plane surface of pre- and postoperative were reflected to 2D plane surface and measured the projection angle which means angle error compared to the preoperative planned position. (Fig.1)

RESULTS

33 TKAs performed with the KA2 system and 44 TKAs with PMI were available for analysis. The mean postoperative HKA was within ±1ã,œof neutral for both groups.

There were no statistically differences between the two groups in coronal component alignment (FFC, FTC). In 3D-CT evaluation, the mean femoral coronal alignment was similar for both groups. On the other hand, PMI group demonstrated significantly more outliers in femoral sagittal alignment compared to the KA2 group (p=0.04). The mean tibial coronal and sagittal alignment were similar for both groups. There was no

significant difference in the average surgical time between the KA2 and PMI groups.

CONCLUSIONS

The KA2 system and CT-based PMI can provide equivalent mechanical alignment in the coronal plane. The KA2 system appears to be superior for femoral sagittal alignment in3D-CT evaluation.

The KA2 system is highly accurate in positioning the femoral component in TKA as compared to CT-based PMI.

Figures

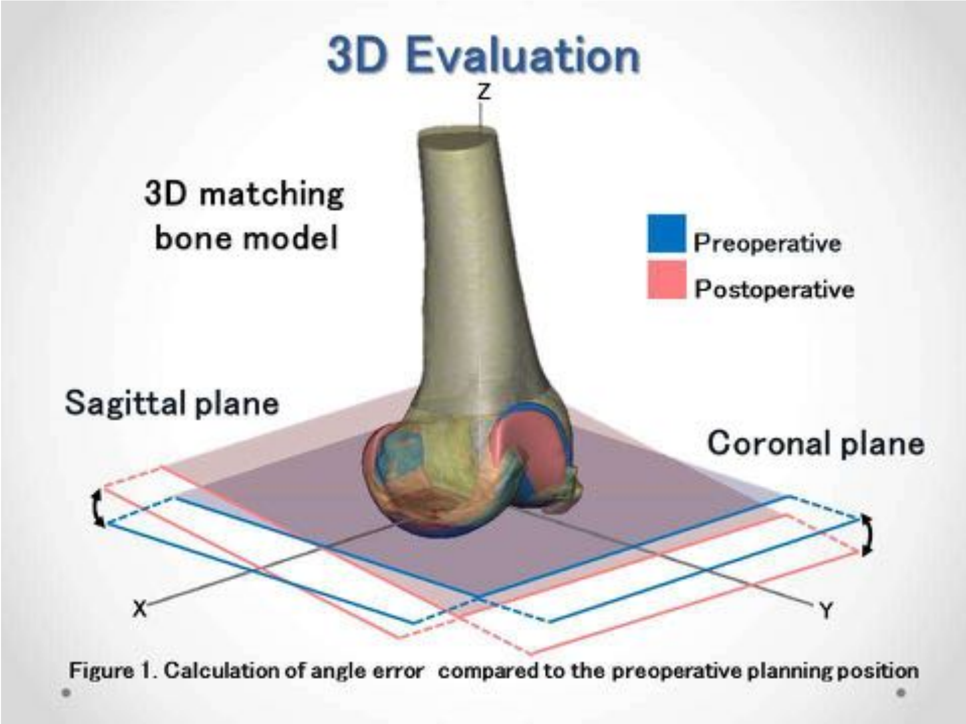
3D Evaluation
Z
3D matching
bone model
Preoperative
Postoperative
Sagittal plane
Coronal plane
X
Y
Figure 1. Calculation of angle error compared to the preoperative planning position

Figure 1

#5571

Improved Accuracy in Total Knee Arthroplasty by CAOS Enhanced Mechanical Instrumentation

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INTRODUCTION

Computer-assisted orthopaedic surgery (CAOS) improves accuracy to total knee arthroplasty (TKA) resections compared to the conventional techniques. However, one of the drawbacks for its adoption is the inconvenience of learning to use CAOS-specific instruments. Enhancing conventional mechanical instruments with CAOS technology may resolve this adoption challenge. This goal of this study was to investigate whether a novel CAOS enhanced mechanical instrument system can help improve alignment accuracy by surgeons with varying experience levels.

Materials and Methods

Eight surgeons (2 seniors, 2 fellows, and 4 residents) resected sawbone knee models targeting neutral alignment (0° varus/valgus). First, each senior and fellow surgeon resected distal femur and proximal tibia (6 knees) using a conventional mechanical instrument system. For the residents, each surgeon performed the same resections on 3 knees. The same resection activities were repeated on a matching set of knee models with CAOS enhancement to the conventional mechanical instrumentation.

The knee models were scanned and digitized at the pre- and post- resections stages. On the intact bone surface, a set of virtual landmarks were annotated to establish the anatomical reference. After registration of the pre- and post- resection digital surfaces, the anatomical reference systems were re-created on the resected bone.

Alignment accuracy in each resection was defined as the signed and unsigned angular deviation between the alignment target (0° varus/valgus) and the *achieved alignment*. The unsigned differences represent the magnitude of resection errors. The signed differences however, identify any bias of the alignment error with a tendency towards more varus or valgus. Accuracy in varus/valgus alignment was compared between conventionally instrumented cases and cases with CAOS enhanced mechanical instrumentation, and across senior, fellow, and resident surgeons. Statistical significance was defined as $p<0.05$.

Results

Adding CAOS enhancement to the conventional instrument system significantly improved varus/valgus alignment accuracy (Fig. 1,2). With just the conventionally instrumentation, those with less experience (follows and residents) had more alignment deviation (both signed and unsigned) than the senior surgeons (p values ≤ 0.017), while no significant difference was found between surgeon experience groups for femoral varus/valgus alignment. In contrast, with CAOS enhancement, all surgeon groups achieved on average ≤ 1° accuracy (signed or unsigned) in both femoral and tibial varus/valgus alignment. None of the CAOS enhanced cases exceeded 3° alignment deviation.

Discussion

This study confirmed significant improvement in coronal alignment accuracy from mechanical instrumentation, when the instrument system is enhanced by CAOS technology. Surgeons with different experience levels all achieved high accuracy in the varus/valgus alignment when the CAOS enhancement was available, compared to the case performed with just mechanical instrumentation.

The CAOS-enhanced mechanical instrument system demonstrated comparable accuracy insensitive to surgeon experience to its corresponding “full-size” CAOS system [1,2]. The system may provide a streamlined solution by adding the benefit of CAOS to the conventional instrumentation without major disruption in the surgical tools and procedure.

REFERENCES

[1] Dai, et al. BJJ. 2017;99-B(SUPP 3),90.

[2] Angibaud, et al. CiOS. 2015;7(2):225-33.

Figures

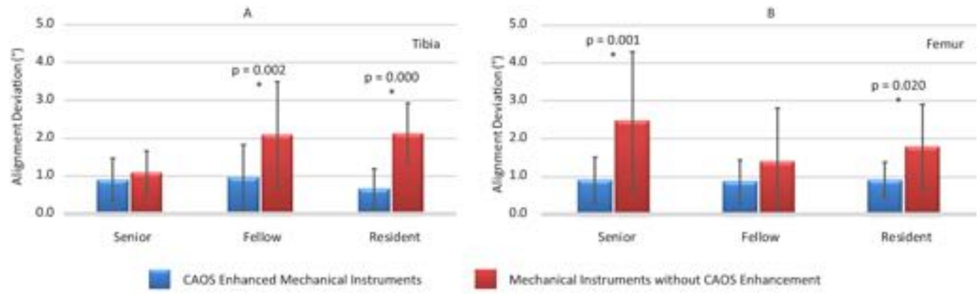

Figure 1. Unsigned alignment deviation in A) tibia and B) femur.Significances found between CAOS enchanced and mechanical instrument only resections were marked with p values.

Figure 1

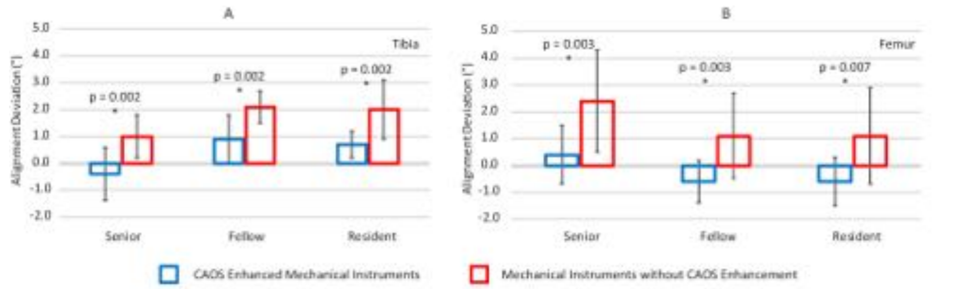

Figure 2. Signed alignment deviation in A) tibia and B) femur.Significances found between CAOS enhanced and mechanical instrument only resections were marked with p values.

Figure 2

#5668

Comparison of Postoperative Radiologic Outcome Between Conventional and Computer Assisted Navigation Total Knee Arthroplasty in Extra-Articular Tibia Vara

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Introduction

The total knee arthroplasty (TKA) is the definite treatment of osteoarthritis. One of the goals of surgical technique at TKA is the creation of symmetric balanced flexion and extension gaps. To achieve the goal, gap balancing and measured resection techniques have been used to determine component position. Failure to correct the malalignment of the mechanical axis of the lower extremity shortens the longevity of TKA.

The extra-articular angulation of the proximal tibia may lead to difficulties in correct implant alignment because of distorted anatomic alignment and landmarks. Balaji et al. reported a significant extra-articular varus angulation of metaphyseo-diaphyseal angle (MDA) greater than 4° is associated with abnormal postoperative hip-knee-ankle angle (HKA).

In recent years, computer assisted navigation TKA (CAS-TKA) has become more popular because of expectation that it will lead to better accuracy in implanting the prosthesis and realigning lower extremities. Literature data show that CAS-TKA increases the accuracy of the proximal tibial cut and offers the capability to track independent lengthening and shortening of the collateral ligaments to facilitate the sizing of a femoral component that properly tenses these ligaments through a full range of motion.

The purpose of this study is to compare between CAS-TKA and conventional TKA for postoperative axis in extra-articular tibia vara.

Materials & methods

A retrospective review of postoperative HKA on standing lower extremity views was conducted in patients who underwent TKA by single surgeon with Columbus® (B. Braun, Melsungen, Germany) implant from 2010 to 2018, dividing into knee with conventional TKA(n=83) and CAS-TKA(n=246).

The extra-articular tibia vara was assessed by measuring the metaphyseo-diaphyseal angle (MDA) (Fig.1) of the tibia in the preoperative standing lower extremity view and the postoperative alignment was assessed by measuring the HKA in the postoperative standing lower extremity view.

Results

Two groups are comparable because there was no statistical significant difference of preoperative HKA and MDA (P=0.306, 0.566, respectively).

No statistical significant difference was found in the postoperative HKA (P=0.416) between two groups. There was no statistically significant difference in case of MDA ≤ 4° in each group (P = 0.351), and also no statistical difference was found in case of MDA > 4° in each group (P = 0.832).

Conclusions

There is no statistical difference in postoperative alignment between conventional TKA and CAS-TKA in extra-articular tibial vara even in the case of MDA > 4° by a skilled surgeon.

Figures

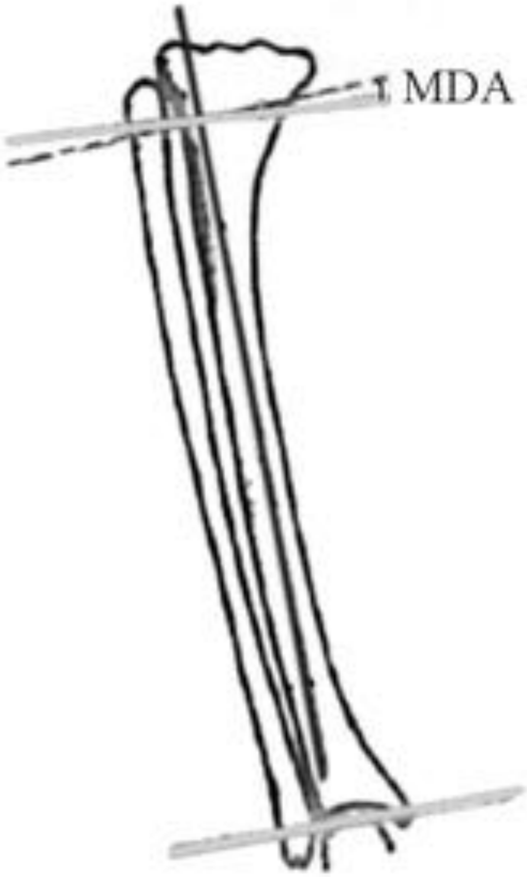

Figure 1

#5573

Learning of a CAOS Enhanced Mechanical Instrument System for Total Knee Arthroplasty: A CUSUM Analysis

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INTRODUCTION

Although computer-assisted orthopaedic surgery (CAOS) increases accuracy in total knee arthroplasty (TKA) compared to the conventional techniques, one of the drawbacks in its adoption is the learning of CAOS-specific instruments. A recent design enhances the existing mechanical instruments with CAOS, removing significant instrument change. While TKA performed by this system can benefit from the improved accuracy, it is important to assess the efficiency in its adoption.

Cumulative sum control chart (CUSUM) has been widely applied to assess the stabilization of industrial production process, and proven to be an effective tool for evaluating learning process in other medical fields. This study used CUSUM to assess the learning of the CAOS enhanced mechanical instrument system.

Materials and Methods

Four surgeons without prior CAOS experience (2 seniors and 2 fellows) each performed proximal tibial and distal femoral resections on six knee models using mechanical instruments, and six more using the same mechanical instrumentation enhanced by CAOS. The cumulative sum of deviances on surgical time [1] was plotted in chronological order for each surgeon. The beginning of a horizontal trend in the plot signified the stabilization of the process, therefore the associated case number (cases to proficiency: CP) was identified as the end of learning. CP was compared between senior and fellow surgeons. The surgical time in CAOS enhanced cases during and after learning was compared to the mechanical instrument only cases on both grouped data and within each surgeon. Significance was defined as $p<0.05$.

Results

The CUSUM plot exhibited three unique phases for each surgeon, with Phase II demonstrating stabilization of the process (Fig 1). No substantial difference between the senior and novice surgeon groups was found in the speed of mastering the CAOS system (CP=2-3 cases). However, the fellows exhibited slightly steeper learning curve than the seniors by adding 3-4 minutes more to their learning cases (Fig 1,2). Compared to the cases with just the mechanical instrumentation, adding CAOS enhancement slightly increased surgical time by 4-6 minutes during learning, and the difference reduced to 2-3 minutes after learning. No significant difference in surgical time was found between senior and fellow surgeons after they mastered the CAOS enhanced mechanical instrument system (Fig 2B).

Discussion

This study applied CUSUM method to analyze adoption of a CAOS enhanced mechanical instrument system for TKA, viewing learning as a process that eventually stabilizes surgical time in critical TKA steps. As the CAOS guidance is based on existing mechanical instruments, adopting the technology required minimum learning effort (2-3 case to learn), independent of the surgeon's experience. The CAOS enhanced system moderately increased the surgical time in critical resection steps by 4-6 minutes during learning. After quick mastering of the technology, the surgical time was only slightly extended by 2-3 minutes compared to case with just mechanical instrumentation. The results demonstrated minimum extension of operative time by introducing CAOS enhancement to existing mechanical instruments, offering the proven benefit of CAOS technology without major disruption in the surgical tools and process.

REFERENCES

[1] Bokhari, et al. Surg Endosc. 2011;25(3):855-60.

Figures

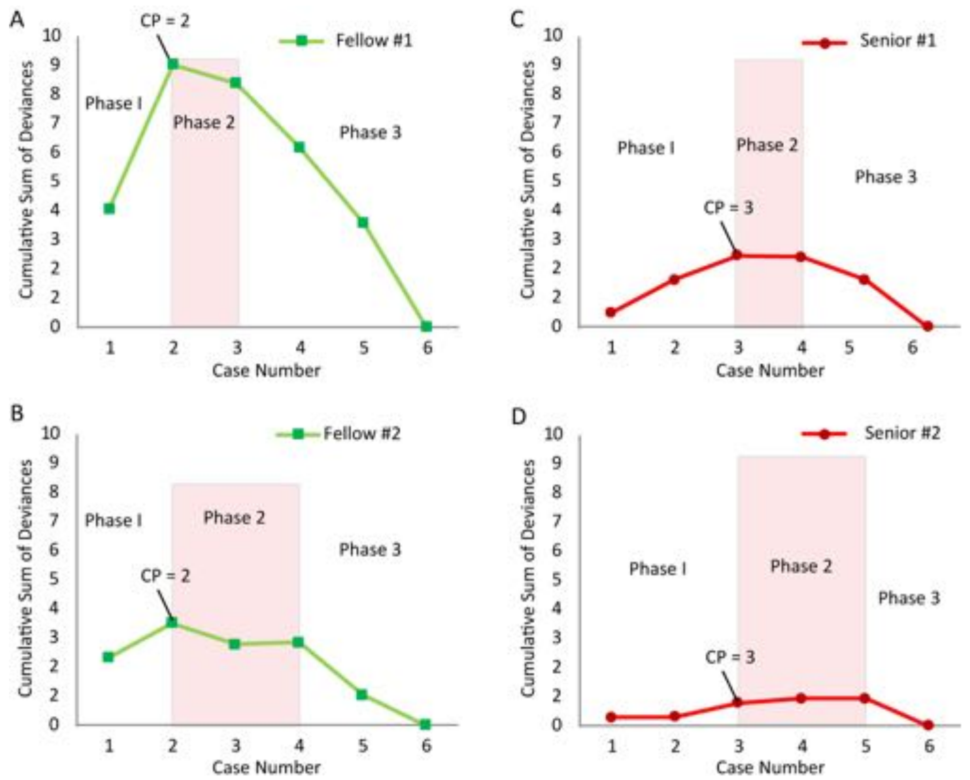

Figure 1. Graphs on the CUSUM deviance charts for A) senior surgeon #1, B) senior surgeon #2, C) fellow surgeon #1, and D) fellow surgeon #2. The fellow surgeons exhibited a steeper learning curve compared to the senior surgeons. The graph was plotted according to the chronological case numbers.

Figure 1

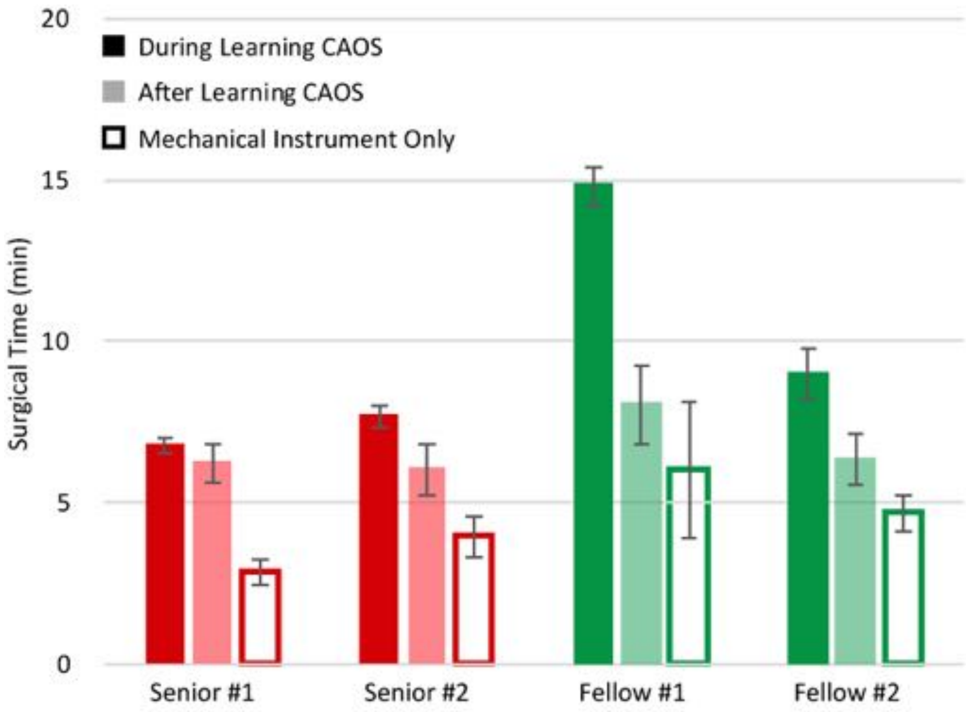

Figure 2. Comparison of surgical time between during learning CAOS enhancement, after learning CAOS enchancement, and mechanical instrumentation only case groups in each individual surgeon. Due to limited cases number per surgeon, statistical assessment of the differences was not performed

Figure 2

Surgical Time (min)	Senior Surgeons	Fellow Surgeons	P
CAOS			
During Learning*	7.3 ± 0.6	11.9 ± 3.4	0.01
After Learning†	6.2 ± 0.6	7.2 ± 1.3	0.07
Mechanical Instrumentation	3.4 ± 0.8	5.4 ± 1.6	0.00
P (Mechanical Instrumentation vs After CAOS Learning)	0.00	0.01	

* Calculated as the average of all learning cases (combining *all surgeons' cases #1 - #CP).*
† Calculated as the average of all after-learning cases (combining all *surgeons' cases #CP+1 - #6).*

Table 1. Summary of learning characteristics in the senior and fellow surgeon groups.

Figure 3

#6205

Condylar Differential in Planned Tibial Cuts in Total Knee Replacement: An Alternative to Computer Navigation

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Background

Mechanics and kinematics of the knee following total knee replacement are related to the mechanics and kinematics of the normal knee. Restoration of neutral alignment is an important factor affecting the long-term results of total knee rereplacement. Tibial cut is a vital and crucial step in ensuring adequate and appropriate proximal tibial resection, which is essential for mechanical orientation and axis in total knee replacement. Tibial cut must be individually reliable, reproducible, consistent and an accurate predictor of individual anatomical measurements. Conventional tibial cuts of tibia with fixed measurements can not account for individual variations. While computer navigated total knee replacement serves as a medium to achieve this objective, the technology is not universally applicable for differing reasons. Therefore we evolved the concept and technique of Condylar Differential for planned tibial cuts in conventional total knee replacement, which accounts for individual variations and reflects the individual mechanical orientation and alignment.

Methods

We used the Condylar Differential in 37 consecutive total knee replacements. We also applied the technique in valgus knees and severe advanced osteoarthritis. First a vertical line is drawn on the digital weight bearing anteroposterior radiograph for mechanical axis of tibia. Then a horizontal line is drawn across and perpendicular to the mechanical axis of tibia. The distances between the horizontal line and the lowest reproducible points of the articular surfaces of the medial and lateral tibial condyles respectively are measured. The difference between the two measurements obviously represents the Condylar Differential. Condylar Differential, adjusted to the nearest millimetre, is maintained in executing the tibial cuts, if necessary successive cuts.

Results

Condylar Differential measurement showed a very wide variation, ranging from 8-6 (2 mm) to 10-0 (10 mm). We found that prior measurement of Condylar Differential is a simple, consistent and effective estimate and individualises the tibial cut for optimal templating of tibia in total knee replacement. We encountered no problems, adopting this technique, in our consecutive series of total knee replacements.

Conclusions

Condylar Differential contributes to optimal individualised tibial cut in conventional total knee replacement and is a useful alternative to computer navigated option with comparable accuracy in this respect. While we used the technique of Condylar Differential in digitised radiographs, this technique can also be applied to plain films, allowing for the magnification.

#6176

Evaluation of Tibial Coronal Aligment With Whole-Leg Standing Radiographs After Total Knee Arthroplasty.

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Introduction: It has been reported that the tibial articular surface of coronal aligment is parallel to the floor in the whole-leg standing radiographs of the normal knee. The purposes of this study are to investigate the relationship between the tibial articular surface and the ground on the whole-leg standing radiographs after total knee arthroplasty(TKA).

Sturdy Design and Methods: 20 knees after TKA were studied retrospectively. The 20 participants were mean age at 76.7 years; and 3 male and 17 female. Using whole-leg standing radiographs, we mesuared the pre- and postoperative hip-knee-ankle angle(HKA), the tibial joint line angle(TJLA), and the tibial component Coronal tibial angle(CTA). The difference in each parameter was compared and examined.

Results: HKA improved from 11.3 ° (varus) to 2.2 ° (varus). TJLA was preoperative - 0.63 ° (varus) to postoperative - 0.17 (varus), and the tibial component was almost parallel to the ground. The CTA was 90.0 ° and it was a good installation position.

Conclusions: In the past kinetic analysis, it is reported that the tibial articular surface tilts outward during walking. By tilting outwardly, load stress may concentrate on the medial compartment. Therefore, the horizontal plane of the joint surface may be advantageous for load distribution at the knee joint. In the result of this study the components were installed horizontally in whole-leg standing position.

#6188

The Effect of Greater External Rotation of the Femoral Component as a Result of Gap Ligament Balancing on Patellar Tracking and Flexion Instability in Total Knee Arthroplasty

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INTRODUCTION

Use of a novel ligament gap balancing instrumentation system in total knee arthroplasty resulted in femoral component external rotation values which were higher on average, compared to measured resection systems. In one hundred twenty knees in 110 patients the external rotation averaged 6.9 degrees (+/- 2.8) and ranged from 0.6 to 12.8 degrees. The external rotation values in this study were 4º and 2º larger, respectively, than the typical 3º and 5º discrete values that are common to measured resection systems. The purpose of the present study was to determine the effect of these greater external rotation values for the femoral component on patellar tracking and flexion instability.

METHODS

One hundred twenty knees in 110 patients were consecutively enrolled by a single surgeon using the same implant across subjects. All patients underwent arthroplasty with tibial resection first and that set external rotation of the femoral component based upon use of a ligament gap balancing system. Following ligament tensioning / balancing, the femur was prepared. The accuracy of the ligament balancing system was assessed by reapplying equal tension to the ligaments using a tensioning bolt and torque wrench in flexion and extension after the bone resections had been made. The resulting flexion and extension gaps were then measured to determine rectangular shape and equality of the gaps. Postoperative Merchant views were obtained on all of the patients and patellar tracking was assessed and compared to 120 consecutive total knee arthroplasties previously performed by the same surgeon with the same implant using a measured resection system.

RESULTS

Rectangular flexion and extension gaps were obtained within +/- 0.5mm in all cases. Equality of the flexion and extension gaps was also obtained within +/- 0.5mm in all cases. Merchant views of the total knee arthroplasties showed central patellar tracking with no tilt or subluxation in 90% of the ligament gap balanced knees and 74% of the measured resection knees.

DISCUSSION AND CONCLUSION

External rotation values are higher on average, when ligament tensioning / balancing is employed with this novel system compared to measured resection systems. In this study this resulted in consistent matching of the flexion gap to the extension gap and better patellar tracking. These findings suggest that limiting the surgeon to discrete rotation values may be at odds with where the femur “desires” to be, given soft tissue considerations for each patient.

#5554

Iatrogenic Bone and Soft Tissue Injury in Robotic-Arm Assisted Total Knee Arthroplasty: A Prospective Cohort Study and Validation of a New Classification System

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Background:

Robotic technology improves accuracy of implant positoing in total knee arthroplasty (TKA) but it is not known how this technology affects the periarticular soft tissue envelope during surgery. The objective of this study was to compare macroscopic bone and soft tissue injury between robotic-arm assisted total knee arthroplasty (RA-TKA) and conventional jig-based total knee arthroplasty (CJ-TKA), and create a validated classification system for reporting iatrogenic bone and periarticular soft tissue injury following TKA.

Methods:

This study included 30 consecutive CJ-TKAs followed by 30 consecutive RA-TKAs performed by a single-surgeon. Intraoperative photographs of the femur, tibia, and periarticular soft tissues were taken prior to implantation of prostheses. Using these outcomes, a macroscopic soft tissue injury (MASTI) classification system was developed to grade iatrogenic soft tissue injuries (Figures 1-3). Inter- and intra-observer validity of the proposed classification system was assessed.

Results

Patients undergoing RA-TKA had reduced medial soft tissue injury in both passively correctible ($p<0.05$) and non-correctible varus deformities ($p<0.05$); more pristine femoral ($p<0.05$) and tibial ($p<0.05$) bone resection cuts; and improved MASTI scores compared to CJ-TKA ($p<0.05$). There was high inter-observer (ICC 0.92 [95% CI: 0.88-0.96], $p<0.05$) and intra-observer agreement (ICC 0.94 [95% CI: 0.92- 0.97], $p<0.05$) of the proposed MASTI classification system.

Conclusion:

There is reduced bone and periarticular soft tissue injury in patients undergoing RA-TKA compared to CJ-TKA. The proposed MASTI classification system is a reproducible grading scheme for describing iatrogenic bone and soft tissue injury in TKA.

Clinical relevance:

Robotic-arm assisted TKA is associated with reduced bone and soft tissue injury compared to conventional jig-based TKA. The proposed MASTI classification may facilitate further research correlating macroscopic soft tissue injury during TKA to long-term clinical and functional outcomes.

Figures

Figure 2: Diagrammatic representation of the macroscpic soft tissue injury (MASTI) score showing tibial plateau in the axial plane

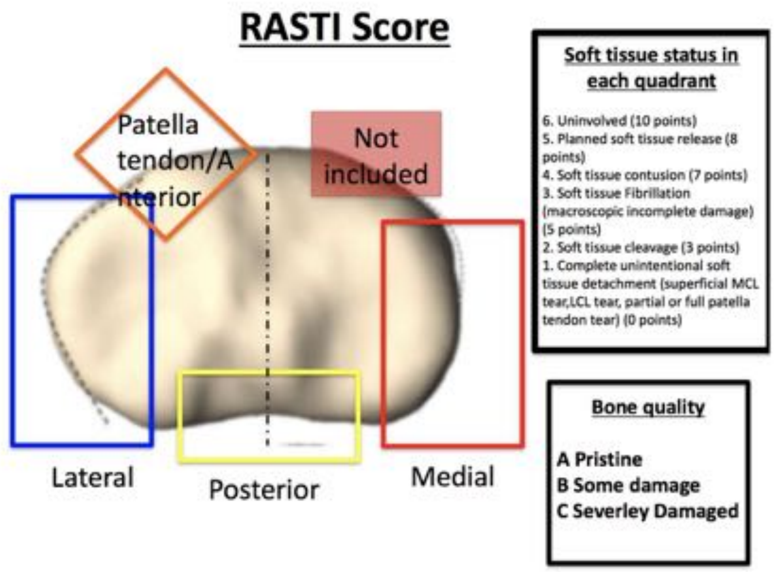

Figure 1

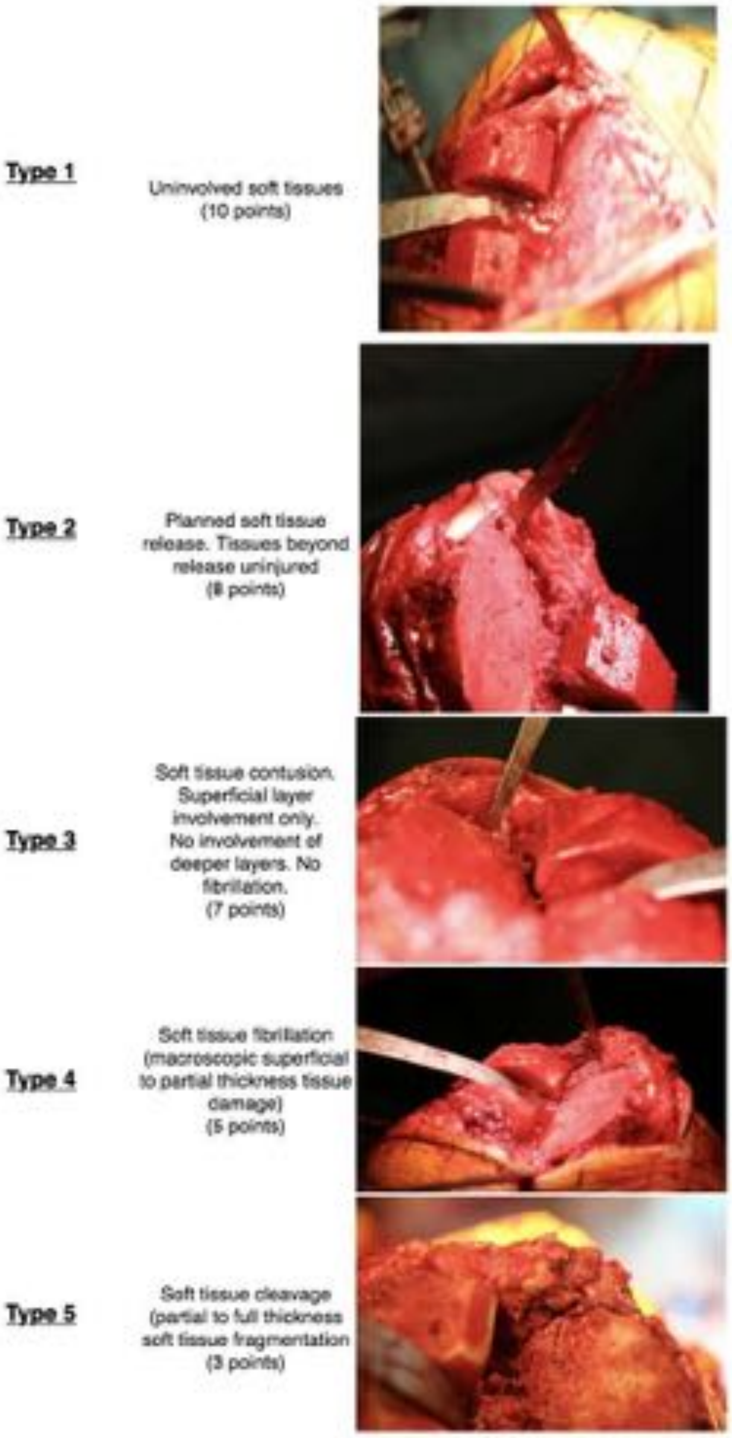

Figure 2

Figure 3: Description of the MASTI classification system

MASTI Classification	Description of soft tissue preservation	Points	Description
Grade A	Excellent	> 34 points	Iatrogenic injury to only 1 zone with relative soft tissue preservation of the other zones
Grade B	Average	25 – 33 points	Minimal iatrogenic injury to ≥2 zones with relative soft tissue preservation of the other zones
Grade C	Poor	< 24 points	Significant iatrogenic soft tissue injury to ≥3 zones
Grade D	Defunctioned Knee	0	Injury to superficial MCL ± LCL ± extensor mechanism defunctioning the knee

Figure 3

#5649

Robotic Arm Assisted Versus Computer Navigated Total Knee Arthroplasty; a Prospective Parallel Study of 150 Patients

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Introduction & Aims

Robotic Arm Assisted Arthroplasty (RAAA) has been reportedly showing improvements in component positioning, alignment restoration and in soft tissue protection.

This prospective parallel study compares outcomes of 75 patients in each group who underwent a Computer Navigated (CN) or a RAAA Total Knee Arthroplasty.

Methods

With institutional ethics board approval patients were assigned to each group. A total of 150 patients were recruited for the study. A single surgeon performed all surgeries, using a standardised technique, similar alignment principles and consistent postoperative care. All demographical information was recorded for each patient as well as a series of outcome measures including EQ5D5L VAS, Mobility & Pain, Forgotten Joint Score, Oxford Score and Knee Injury and Osteoarthritis Outcome Score (KOOS-WOMAC).

Other relevant clinical information detailed, included self-reported satisfaction levels, length of stay (LOS), blood loss, range of motion, theatre time, tourniquet time, analgesia requirements and postoperative pain.

Results

Eighty nine women and 61 men participated in the study. There was no difference in BMI or patient reported satisfaction between the groups. The mean LOS was 3.05 for the RAAA group and 4.1 for the CN group, $p<0.001$. There was no significant difference found between the groups reported outcome scores. No significant difference in Haemoglobin was found between the groups. There was a statistically significant difference in inpatient total morphine equivalent consumption noted between the groups, RAAA 173 units v CN 262 units, ($p=0.001$). Using a negative binomial regression model controlling for age, gender, weight and height, it was found that undergoing a CN TKA resulted in a 25% increase in, inpatient length of stay and that the length of stay increased by 4% for every 50 unit increase in total morphine equivalent consumed (Incidence Rate Ratio 1.04, $p=0.006$, 95% CI 1.01 – 1.07).

Conclusion

Compared to Computer Navigation, Robotic Arm Assisted Total Knee Arthroplasty resulted in significantly improved postoperative pain, reduced total morphine consumption and reduced length of stay. Although encouraging, the authors note that further larger scale clinical comparative studies assessing outcomes from Robotic Arm Assisted Arthroplasty Surgery are needed.

#6013

Can Surgical Technology Reduce Surgical Staff Postural Demands During Total Knee Arthroplasty

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Introduction: Hospital staff routinely take on ergonomically challenging tasks with one study indicating 62% exhibited non-neutral shoulder positions and 53% had non-neutral back positions while working in the OR [1]. This study examined an OR surgical assistant's posture while assisting with manual total knee arthroplasty (MTKA) and robotic-arm assisted TKA (RATKA).

Methods: An OR surgical assistant's posture and muscle activity were monitored while assisting a single high-volume TKA surgeon who performed three MTKA and three RATKA on cadaveric knees. The role of the assistant was to assist the surgeon with soft tissue retraction, instrument placement, removal of cut bone, and to hand instruments to the surgeon.

Movement sensors were used to monitor the assistant's lower back and shoulder posture. Flexion angle of the lower back was assessed with a sensor placed on the L5/S1 region and a second placed on the T1/L1 region. Elevation angle of the shoulder was measured by placing a sensor on the anterolateral surface of the right and left humeri. Baseline movement angles were established by having the assistant stand in a relaxed position prior to performing TKAs. All data collected from MTKA and RATKA were separated by surgical task. Shoulder and back were assessed using a scoring system that considered percentage of time in a range of movement zone, number of repetitions, length of time in a sustained position, and average muscle activity (Table 1). Scoring ranged from 0 to 8, with 8 representing a task with the highest risk.

Results: For all MTKA procedures, the assistant had the highest kinematic scores during bone cutting and instrument placement. For RATKA, the assistant had limited participation during bone cutting, and no instrument placement was required. For surgical tasks unique to RATKA, such as array placement and bone registration, kinematic scores were lower than MTKA tasks (Figure 1). When considering all surgical tasks, femoral bone cutting and instrument placement had the highest scores based on range of movement, repetitions, and sustained position. For both MTKA and RATKA, there was minimal flexion of the lower back.

Discussion: Results from this study indicated RATKA may reduce ergonomic risks to a surgical assistant during TKA. This reduced risk was attributed primarily to the assistant no longer needing to participate in instrument placement and reduced participation in soft-tissue retraction throughout the case. Literature has listed soft tissue retraction as the surgical task with the leading ergonomic risk to OR staff [2]. The RATKA procedure included self-retaining retractors that can hold soft tissues during surgery without needing the aid of the assistant. By decreasing the need for this task alone, the risk of musculoskeletal injuries to the OR staff may be reduced. The current study included a small sample size to determine which tasks were most demanding on the assistant. Future studies will be needed with a larger sample size as well as in an OR setting to fully understand how RATKA may reduce potential ergonomic risks to a surgical assistant.

References: [1]OR Manager monthly. 2005,Jul;21(7):6-8. [2]Abdollahzade, Health Promotion Perspectives. 2016,6(1):17-22.

Figures

Criteria	High	Medium	Low
Range of Movement (ROM) Zone	Elevation above 60°	Elevation between 30° and 60°	Elevation below 30°
% Time in ROM Zone	Time shoulder is in High ROM Zone is ≥ 10%	Time shoulder is in Medium ROM Zone is ≥ 20% AND does not enter High ROM Zone	> 70% time in Low ROM Zone AND not in High or Medium ROM Zones
Repetitions	≥ 2 rep/min with shoulder held in High ROM Zone	≥ 2 rep/min with shoulder held in Medium ROM Zone AND does not enter High ROM Zone	< 2 rep/min in either High or Medium ROM Zones
Sustained Positions	High ROM Zone position sustained > 30 second	Medium ROM Zone position sustained > 30 second AND does not enter High ROM Zone	No sustained positions > 30 seconds in either High or Medium Zones
Score Range	**5-8**	**1-4**	**0**

Figure 1

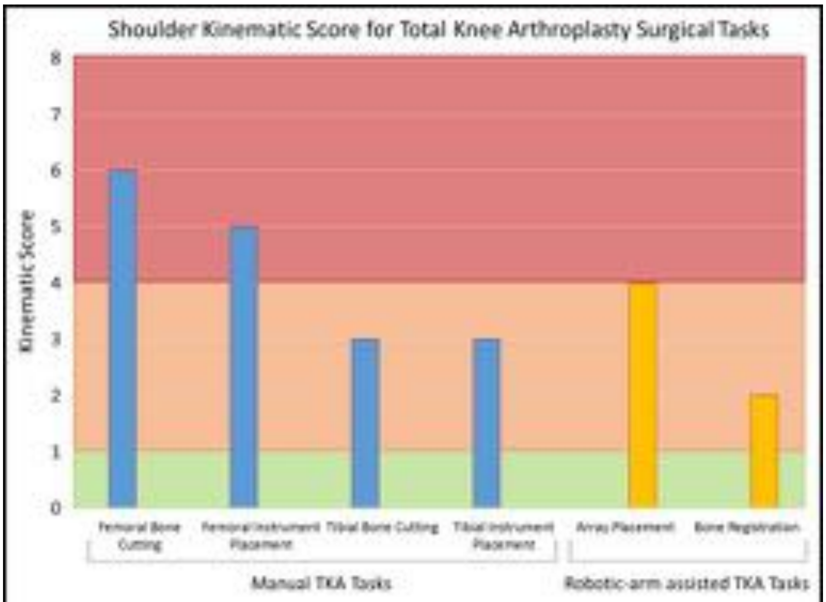

Figure 1. Shoulder kinematics were assessed for surgical tasks during total knee arthroplasty (TKA). Scores are provided for tasks specific to manual and robotic-arm assisted TKA.

Figure 2

#5813

Robotic Total Knee Arthroplasty With a Semi-Active Haptic Guided Technique Is Safe and Reliable

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Background

Use of a robotic tool to perform surgery introduces a risk of unexpected soft tissue damage due to the lack of tactile feedback for the surgeon. Early experience with robotics in total hip and knee replacement surgery reported having to abort the procedure in 18-34 percent of cases due to inability to complete preoperative planning, hardware and soft tissue issues, registration issues, as well as concerns over actual and potential soft tissue damage. These damages to the soft tissues resulted in significant morbidity to the patient, negating all the desired advantages of precision and reproducibility with robotic assisted surgery. The risk of soft tissue damage can be mitigated by haptic software prohibiting the cutting tip from striking vital soft tissues and by the surgeon making sure there is a clear workspace path for the cutting tool. This robotic total knee system with a semi-active haptic guided technique was approved by the FDA on 8/5/2015 and commercialized in August of 2016. One year clinical results have not been reported to date.

Objective

To review an initial and consecutive series of robotic total knee arthroplasties for safety in regard to avoidance of known or delayed soft tissue injuries and the necessity to abort the robotic assisted procedure and resort to the use of conventional implantation. Report the clinical outcomes with robotic total knee replacement at or beyond one year to demonstrate satisfactory to excellent performance.

Methods

The initial consecutive series of 100 robotic total knee replacements using a semi-active haptic guided system including 34 from the initial IDE series in 2014 and those performed after commercial approval beginning in 2016 were reviewed. Pre-operative planning utilizing CT determined the implant placement and boundaries and thus the limit of excursion from any part of the end effector saw tip. Self-retaining retractors were also utilized. Operative reports, 2, 6, and 12 week, and yearly follow-up visit reports were reviewed for any evidence of inadvertent injury to the medial collateral ligament, patellar tendon, or a neurovascular structure from the cutting tool. Operative notes were also reviewed to determine if the robotic procedure was partially or completely aborted due to any issue. Knee Society and Functional scores were recorded from pre-operative and yearly.

Results

No cases were unable to be completed robotically. No case had evidence for acute or delayed injury to the medial collateral ligament, patellar tendon, or neurovascular structure. The average follow-up for this series was 1.54 years. Average pre-operative Knee Society and Functional Scores improved from 44.7 and 50 to 98.1 and 87.8 at one year follow-up, 93.8 and 83.1 at two year follow-up, 98.5 and 87.7 at three year follow-up, and 99 and 85 at four year follow-up.

Conclusions

A semi-active haptic guided robotic system is a safe and reliable method to perform total knee replacement surgery. Preliminary short-term outcomes data shows excellent clinical and functional results.

#6016

Does the Use of Robotic Technology Improve a Surgeons Cervical Ergonomics and Their Overall Satisfaction?

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Introduction: Orthopaedic surgery can be a highly demanding procedure on a surgeon's musculoskeletal health. Studies have reported 44-66% of surgeons surveyed have had a work-related injury with 10-27% requiring surgery. Of these, neck injuries typically have one of the highest incidences. These injuries have been attributed to poor surgeon posture, such as increased or sustained neck flexion. Robotic technologies have been introduced into the operating rooms to assist surgeons with ergonomically challenging surgical tasks. These technologies include elements that can reduce the physical stress on the surgeon's neck, such as heads-up displays to visualize the surgical case and self-retaining retractors to minimize assistance during exposure.The purpose of this study was to establish how the use of robotic technology implemented during Total Knee Arthroplasty (TKA) procedures influences a surgeon's cervical posture as well as to understand their surgical fatigue and overall satisfaction.

Methods: 12 TKAs (6 cadaver specimens) were performed by 2 high-volume TKA surgeons. For each cadaver, MTKA was performed on one knee and RATKA on the contralateral knee. For a single surgeon, kinematic sensors were placed on the occiput and T3 to measure flexion and extension of the head and neck relative to a baseline positioned. Mean head and neck angles, percentage of time at angles, and number of repetitions were reported for each surgical task and as a cumulative mean for the entire TKA procedure. Mean head angles were used to calculate the expected forces on the cervical spine by using methods established in literature. Following each surgical case, both surgeons were asked a series of questions to assess physical and mental fatigue as well as overall satisfaction. Providing scores 1-10, where a higher score correlates to increased fatigue and satisfaction.

Results: Mean head (occiput) flexion angle for MTKA was higher than that measured for RATKA (28° vs 18°, respectively, figure1). This correlated to greater forces on the cervical spine of approximately 38-lbs for MTKA and 30-lbs for RATKA. When considering common surgical tasks, the largest difference in head angle between the two approaches occurred while the surgeon was performing bone cuts and preparation of the knee which includes bone registration and soft tissue balancing for RATKA and manual instrument placement for MTKA. From the surgical questionnaire, RATKA had reduced metal fatigue for bone cuts and knee preparation when compared to MTKA (1.5 vs 2.2 and 2.5 vs 2.7, respectively). Furthermore, RATKA had increased overall satisfaction compared to MTKA (8.8 vs 8.0, respectively).

Conclusion: Poor ergonomic posture may lead to development of cervical musculoskeletal overuse injuries. To enhance surgeon ergonomics in the operating room, it is important to understand potential ergonomic risk factors and how the use of certain technologies may help to reduce those risks. Based on a limited sample size, robotic technology has potential to increase surgeon satisfaction and reduce risk of mechanical trauma to the surgeon. This data will need to be verified in a clinical setting.

Figures

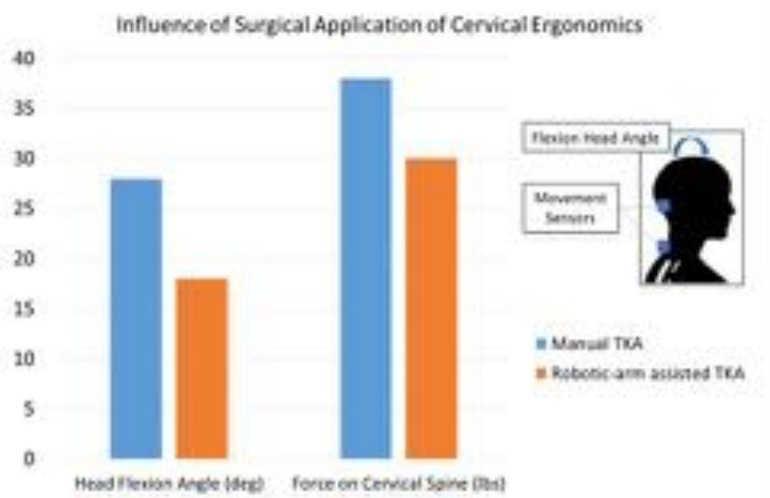

Figure 1. When compared to RATKA, MTKA had increased head flexion and therefore expected force on the cervical spine.

Figure 1

#5952

Robotic Knee Surgery Produces a Reproducible and Balanced Knee Construct When Compared to Conventional TKA.

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Introduction: The introduction of robotic surgery and sensor integrate technology, allows the opportunity to delineate the role of existing and novel devices upon the final total knee arthroplasty (TKA) construct: METHODS: We performed a paired cadaveric study to define the impact of robotic surgery against conventical TKA. Using validated measures of laxity in 6 degrees of freedom and true real time load sensing we compared 2 states; TKA using Robotic Surgery (R-TKA) and TKA using standard Measured resection instrumentation (TKA-S). Side of intervention was randomised. All Knees underwent preoperative and post-operative CT for alignment. Our null hypothesis was that component rotation, load and laxity would not improve with robotic surgery. RESULTS: Surgery was performed on 5 pairs of cadaveric knees; At the time of writing provisional data was available. In all the laxity pattern was equivalent for TKA-R and TKA-S. However Robotic TKA archived a balanced construct with <15lb medial - lateral load difference throughout the full arc of flection (0^0-110^0). In all standard TKA constructs despite clinical assessment confirming equivalence of flexion extension gap and centralisation of collateral ligament distraction there remained a >15lb medial to lateral load difference for at least two points of the flexion arc. Post-operative CT confirmed satisfactory component alignment had been achieved with all knees postoperatively. CONCLUSION: The concept of a balanced knee thought the arc of flexion remains poorly defined. The clinical assessment of a balanced construct fails to identify changes in tibiofemoral load. The ability to achieve a consisted medial and lateral tibiofemoral load is improved with robotic surgery. This work has served to highlight the small margin of safety with TKA and the used of emergent technology to improve operative outcomes.

#6181

Robotic Assisted Total Knee Arthroplasty in Patients With Severe Varus Deformity

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Introduction : In severe varus knee deformity, the image free computer navigation TKA may result in a malaligned knee. The aim of this study was to compare the clinical and radiological results of Robotic assisted TKA in patients with severely varus knee (more than 15°)

Materials and Methods: 136 osteoarthritic knees having Robotic assisted TKA were involved in this study. A study group of 31 patients with a mechanical axis of less than varus 8° (mean 5.83 degree of varus). B study group of 75 patients with a mechanical axis of 8 to 15 degree of varus (mean 11.52 degree of varus) and C study group of 30 patients with a mechanical axis of more than 15 degree (mean 19.48 degree of varus) were compared. Knee society score (KSS) was used for clinical evaluation preoperatively and postoperatively. A hip-knee-ankle axis in full weight bearing standing radiography was measured for axis evaluation and implant positions were measured in standard knee radiography. All patients were followed at mean of 2.5 years (range 2-4 years)

Results : Preoperatively, Group C showed inferior clinical results (more varus deformity, less range of motion, more obese, less KS scores), however, there was no differences of clinical results at final follow-up. Overall, neutral alignment was obtained in 93.8 %. Outliers (more than 3 degree of mechanical axis) were founded more in severe varus knee groups. No outliers was founded in group A, 5 outliers (6.6%) in group B and 4 outliers (14%) in group C. No significant difference was observed in implant position among three groups.

Conclusion: Robotic assisted TKA showed excellent clinical and radiological results. Especially neural alignment could be obtained in 93.8%. However, varus aligned TKAs were founded more frequently in severely deformed varus knees

#5961

Quality of Systematic Reviews Comparing Conventional and Computer-Assisted Joint Replacement

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Background: Effectiveness of computer-assisted joint replacement (CA-TJR) compared to conventional TJR has been evaluated by a large body of literature. Systematic reviews provide a powerful, widely accepted, evidence-based approach to synthesize the evidence and derive conclusions, yet the strength of these conclusions are dependent on the quality of the review. Multiple systematic reviews compared CA-TJR and conventional TJR with conflicting results. We aimed to assess the quality of these reviews.

Methods: We searched the MEDLINE, EMBASE, Chocrane library, and Epistemonikos databases to identify systematic reviews published through May 2017 that compared CA-TJR and conventional TJR. No language restrictions were imposed. The search strategy combined keywords (e.g., knee arthroplasty, hip arthroplsty) with subject heading terms (e.g., surgery, computer assisted, arthroplsty, replacement, knee, hip), and specialized clinical queries for systematic reviews. We also searched conference proceedings and the grey literature. One reviewer conducted title and abstract screening for all resulting citations. Full-text articles that met the inclusion criteria were retrieved and assessed independently by 2 reviewers for their methodological quality using the AMSTAR-2 tool, a valid and reliable tool for assessing the quality of systematic reviews (Shea et al., 2017). AMSTAR-2 has 16 domains, of which 7 are critical (e.g., justification for excluding individual studies) and 9 are non-critical (e.g., not reporting conflict of interest for inidvidual studies). Reviews are rated as high (no critical or non-critical flaws), moderate (only non-critical flaws), low (1 critical flaw) and critically low (more than one critical flaw). Disagreement between the 2 reviewers was resolved by discussion with the senior author to achieve consensus. We reported the quality ratings of these studies and the frequency of critical and non-critical flaws.

Results: of 384 citiations originally identified, 38 systemtic reviews were included (Figure 1), of which 6 synthesized evidence qualitatively and 32 conducted meta-analyses. Based on AMSTAR-2 tool, 1 study was rated low and the remaining 37 studies were rated critically low. Failure in meeting the following critical domains resulted in the low rating: 37 (98%) reviews did not report the protocol registration; 32 (84%) reviews did not justify excluding studies; 27 (68%) reviews did not account for risk of bias in the primary studies when interpreting the results; 20 (52%) failed to use comprehensive literature review strategies; 17 reviews with meta-analyses failed to justify the use of appropriate methods for statistical combination of results from randomized controlled trials (RCTs) (48%) and non-randmoized studies (44%), and 16 (42%) meta-analyses did not use satisfactory to assess risk of bias of RCTs; and finally 16 (42%) studies failed to report publication bias. Non-critical flaws were also prevalent (Figure 3).

Conclusions: Despite the relatively large number of published systematic reviews comparing CA-TJR and conventional TJR, quality of these reviews was critically low, raising significant concerns about the conclusions derived from these reviews. Our study identified areas to improve the quality of future reviews, and therefore, result in more robust conclusions.

Figures

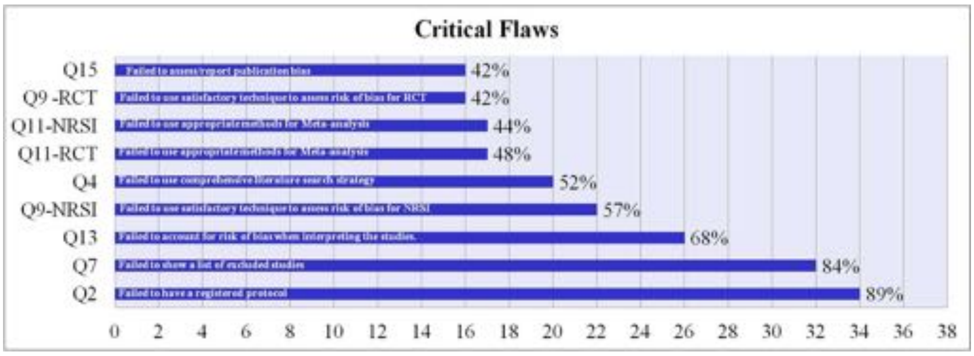

Figure 1

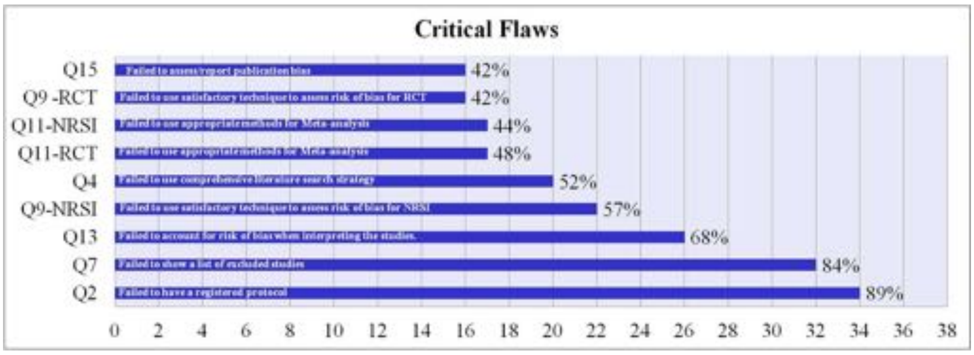

Figure 2

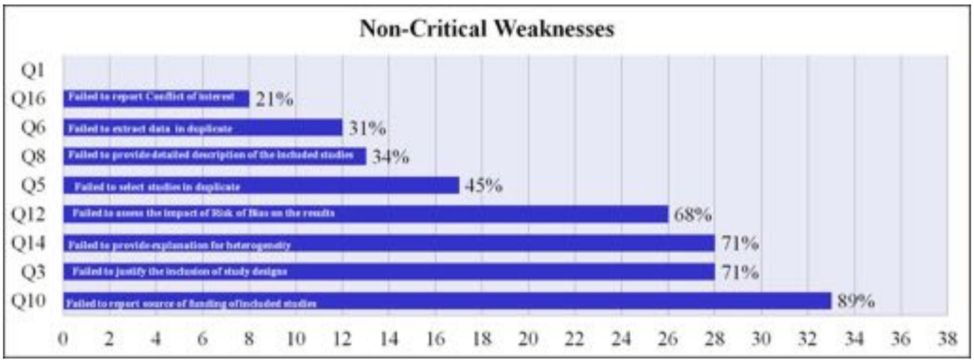

Figure 3

#6046

Assessing the Learning Curve for Robotic-Arm Assisted Total Knee Arthroplasty: a Look at Operative Times and Reoperations

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Introduction:

Adaptation of robotic surgical instruments raises concerns regarding duration of surgery and adverse events. This study reports on the initial experience of three arthroplasty specialists (A, B, and C) with robotic arm assisted total knee arthroplasty (TKA) at our institution.

Methods:

We retrospectively reviewed each surgeon's robotic TKA (N = 304, 122, and 209 for A, B, and C respectively). Exponentially weighted moving average (EWMA) charts were plotted in Minitab 17 to examine when operative times attained steady state. With EWMA, the weight attached to data exponentially decreases with older observations. Commonly accepted weighting factor of 0.2 was applied. We compared mean operative times and reoperations for conventional TKA versus robotic cases. Mini-midvastus surgical approach was utilized for all procedures.

Results:

Surgeon A achieved steady state after 28 cases with pre-steady state mean (Std. Dev) time of 92.4 (10.7) minutes. Subsequent mean time of 77.5 (8.8) minutes (N = 276) was significantly higher than the 62.9 (9.5) minutes for conventional (N = 396). Surgeon B realized steady state after case 6 with mean time of 139.8 (18.5) minutes. Subsequent mean time of 115.5 (17.4) minutes (N = 116) was significantly higher than the 102.5 (14.5) minutes for conventional (N = 134). Surgeon C attained steady state after 10 cases with mean time of 124.6 (13.5) minutes. Afterwards mean time was 104.8 (16.9) minutes (N = 199), comparable to the 106.3 (17.4) minutes for conventional (N = 136, P-Value = 0.409).

Surgeon A's pre-steady state reoperation rate of 14.3% was significantly higher than the 0.4% and 1.3% for steady state and conventional cases respectively. B had a 3.0% reoperation rate for conventional cases, and no reoperation for robotic cases. C had a 0.5% (none pre-steady state) and 1.5% reoperation rate for robotic and conventional cases respectively.

Conclusion:

Robotic arm assisted TKA can be rapidly, and safely adapted into a high volume arthroplasty practice. Our most experienced surgeon (A) took 28 cases to achieve steady state, which was longer than the lower volume surgeons. Future prospective randomized trials will be necessary to evaluate whether robotic TKA imparts a clinical advantage over traditional cutting guides.

#5687

A Bibliometric Analysis of Robotic Assisted Hip and Knee Arthroplasty

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Introduction and aims:

The Australian and International Orthopaedic communities are eagerly adopting Robotic Arm Assisted Arthroplasty (RAAA) technology. However, the evidence for the benefits of this technology are unproven and at best equivocal. This study is a comprehensive bibliometric analysis of all published research in the field of RAAA.

Methods:

A systematic literature search was conducted to retrieve all peer-reviewed, English language, publications studying robot-assisted hip and knee arthroplasty between 1992 and 2017. Review articles were excluded. Articles were classified by type of study and level of evidence according to the Oxford Centre for Evidence-based Medicine (OCEBM) Levels of Evidence System. The number of citations, authorship, year of publication, journal of publication, and country and institution of origin were also recorded for each publication.

Results:

We identified 73 original studies published since 1992 in the field of robotic arthroplasty. The procedures reported were total hip and total knee replacement, and uni-compartmental knee replacement. Publications originated from 17 countries and 117 organisations. Fifty percent of studies identified were published in the last 5 years at an average of 7 publications per year, compared to an average of 2.7 publications per year from 1992 to 2012. Thirty-six percent of original studies were of level 5 evidence or below, with a preponderance of biomechanical and cadaveric studies. The most cited paper was Bargar, Bauer and Borner's original RCT proving efficacy and safety of the Robodoc system for total hip replacement.[1] Most publications originated in the US (36.9%) and more than 15% were published in the Journal of Arthroplasty.

Conclusions:

Analysis of publication patterns in Robotic Orthopaedic surgery allow us a unique insight into the qualities, characteristics, clinical innovations and advances in the evolution of robotic orthopaedic arthroplasty research.

1. Bargar W, Bauer A, Borner M. Primary and revision total hip replacement using the Robodoc ® system. Clin Orthop Relat Res. 1998 Sep;(354):230-8.

#6138

Can the Use of Robotic Technology Reduce Surgical Variability and Mental Exertion When Performing Total Knee Arthroplasty?

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INTRODUCTION: A careful evaluation of new technologies such as robotic-arm assisted total knee arthroplasty (RATKA) is important to understand the reduction in variability among users. While there is data reviewing the use of RATKA, the data is typically presented for experienced TKA surgeons. Therefore, the purpose of this cadaveric study was to compare the variability for several surgical factors between RATKA and manual TKA (MTKA) for surgeons undergoing orthopaedic fellowship training.

METHODS: Two operating surgeons undergoing orthopaedic fellowship training, each prepared six cadaveric legs for cruciate retaining TKA, with MTKA on one side (3 knees) and RATKA on the other (3 knees). These surgeons were instructed to execute a full RATKA or MTKA procedure through trialing and achieve a balanced knee. The number of recuts and final poly thickness was intra-operatively recorded. After completion of bone cuts, the operating surgeons were asked if they would perform a cementless knee based on their perception of final bone cut quality as well as rank the amount of mental effort exerted for required surgical tasks. Two additional fellowship trained orthopaedic assessment surgeons, blinded to the method of preparation, each post-operatively graded the resultant bone cuts of the tibia and femur according to the perceived percentage of cut planarity (grade 1, <25%; grade 2, 25-50%; grade 3, 51-75%; and grade 4, >76%). The grade for medial and lateral tibial bone cuts was averaged and a Wilcoxon signed rank test was used for statistical comparisons. Assessment surgeons also determined whether the knee was balanced in flexion and extension. A balanced knee was defined as relatively equal medial and lateral gaps under relatively equal applied load.

RESULTS: Operating surgeons used 9mm polys in all 6 RATKA specimens, and 3/6 MTKA specimens. Operating surgeons said they would do cementless in 4/6 RATKA specimens, and 1/6 MTKA specimen. In MTKA specimens, 5/6 cases had a recut on the tibia or femur to obtain knee balance. With RATKA, 1/6 cases had a recut on the tibia. With RATKA, operating surgeons performed a pre-resection balancing workflow, and made plan adjustments prior to resection. The operating surgeons reported reduced mental effort when performing bone measurements, tibial bone cutting, knee balancing, trialing, and post-resection adjustments with RATKA compared to MTKA. Mental effort was equivalent during femoral bone cutting between the two procedures and increased for RATKA during initial exposure and retractor setup. Assessment surgeons considered all 6 RATKA and 2/6 MTKA specimens to be balanced. Assessment surgeons assigned RATKA specimens a higher grade for perceived planarity (3.86 vs. 3.48, p=0.03) than MTKA specimens.

DISCUSSION: In this cadaveric study, RATKA resulted in a higher usage of minimum poly thickness, greater tendency to want to use cementless components, higher number of balanced knees, higher perceived planarity, lower number of recuts, and reduced mental effort than MTKA cases. RATKA may give users more confidence in performing cementless TKA, especially for novice surgeons. Robotic-arm assisted TKA may allow for reduced surgical variability, which may improve patient outcomes, and should be investigated in a clinical setting.

#5553

The Learning Curve Associated With Robotic-Arm Assisted Unicompartmental Knee Arthroplasty

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Objective:

The primary objective of this study was to determine the surgical team's learning curve for introducing robotic-arm assisted UKA into routine surgical practice. The secondary objective was to compare accuracy of implant positioning and limb alignment in conventional jig-based UKA versus robotic-arm assisted UKA.

Methods:

This prospective single-surgeon cohort study included 60 consecutive conventional jig-based UKAs compared with 60 consecutive robotic-arm assisted UKAs for medial compartment knee osteoarthritis. Surrogate measures of the learning curve were prospectively collected. These included operative times, the state-trait anxiety inventory (STAI) questionnaire to assess preoperative stress levels amongst the surgical team, accuracy of implant positioning, limb alignment, and postoperative complications.

Results:

Robotic-arm assisted UKA was associated with a learning curve of six cases for operating time ($p<0.001$) and surgical team comfort levels ($p<0.001$) (Figure 1a-c). Cumulative robotic experience did not affect accuracy of implant positioning ($p=0.52$), limb alignment ($p=0.65$), posterior condylar offset ratio ($p=0.71$), posterior tibial slope ($p=0.68$), and native joint line preservation ($p=0.55$). Robotic-arm assisted UKA improved accuracy of implant positioning ($p<0.001$) and limb alignment ($p<0.001$) with no additional risk of postoperative complications compared to conventional jig-based UKA.

Conclusion:

Robotic-arm assisted UKA was associated with a learning curve of six cases for operating time and surgical team comfort levels but no learning curve for accuracy of implant positioning or limb alignment.

Clinical significance:

Implementation of robotic-arm assisted UKA into routine surgical practice does not have a learning curve for accuracy of implant positioning and limb alignment. Surgical teams may take up to six cases to get accustomed to the altered workflow with increased operating times observed during this initial learning phase.

Figures

Figure 1: Charts displaying CUSUM analysis for study patients undergoing UKA.

Figure 1a – Chart plotting CUSUM analysis for operative times in all 120 consecutive UKA procedures. The solid vertical line represents transition from conventional jig-based UKA to robotic arm-assisted UKA. The dashed vertical line represents transition between Phase 1 (learning) and Phase 2 (proficiency) of the learning curve for robotic-arm assisted UKA

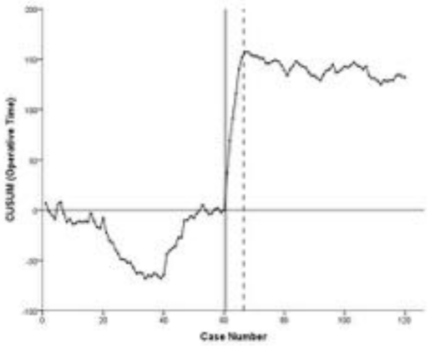

Figure 1

Figure 1b - Chart plotting CUSUM analysis for phase 1 of operative times in consecutive robotic-arm assisted UKA procedures

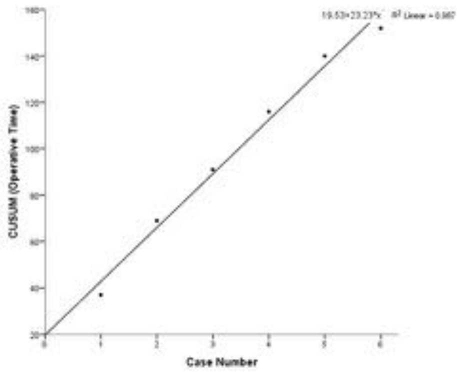

Figure 2

Figure 1c - Chart plotting CUSUM analysis for phase 2 of operative times in consecutive robotic-arm assisted UKA procedures

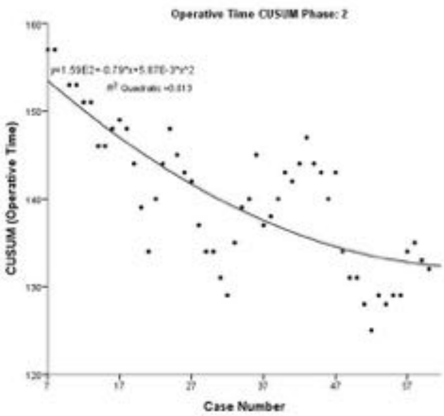

Figure 3

#5817

Energy Expenditure During Conventional and Robotic Arm-Assisted Total Knee Arthroplasty

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Abstract:

Introduction: The purpose of this study is to compare total and rate of caloric energy expenditure between conventional and robotic-arm assisted total knee arthroplasty (TKA) between a high volume “veteran” surgeon (HV) and a lower volume, less experienced surgeon (LV).

Methods: Two specialized arthroplasty surgeons wore a biometric-enabled shirt and energy expenditure outcomes were measured (total caloric expenditure, kilocalories per minute, heart rate variability, and surgical duration) during 35 conventional (CTKA) and 29 robotic primary total knee arthroplasty (RTKA) procedures.

Results: Overall, the rate of caloric expenditure was similar between RTKA (5.60 ±2.50 kcal/min) and CTKA (4.79cal/min ±1.79, p=0.25). With 6.15 minute longer operative times, the total energy expenditure (TEE) for RTKA (239.31±96.79 kcal) was higher thanCTKA(181.54 ±80.90 kcal, p<0.001). The HV surgeon’s TEE (p<0.001) and rate of energy expenditure (REE) (p<0.001) were significantly higher in RTKA (261.53cal; 6.499cal/min) versus CTKA (71.00cal; 3.759cal/min). However, the LV surgeon’s TEE and REE for RTKA (207.83cal; 4.32cal/min) and CTKA (195.81cal; 4.92cal/min) were not significantly different (p>0.05). Both surgeons (HV; LV) had significantly longer surgical durations (p<0.001) in RTKA (40.41 ±4.94min; 48.91 ±8.45min) compared to CTKA surgeries (18.75±4.27min; 40.4 ±8.34min), respectively.

Conclusion: While REE did not varybetween CTKA and RTKA for the LV surgeon, it did vary significantly for the HV surgeon. Additionally, RTKA took longer and increased TEE, but one less operating room assistant was needed. Surgeons with less experience in TKA may be less likely to notice a difference in energy expenditure when utilizing robotic-arm assisted technology. It is possible that more experience with using the robotic arm could create efficiencies over time that may also reduce TEE.

#6182

Comparison of Blood Loss Between Robotics Assisted and Convention 1 Week Interval Staged Bilateral TKA

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Computer assisted TKA can avoid opening the intramedullary canal and have a potential advantage in blood loss. However, previous studies reported controversial results. The purpose of this study was to investigate the effect of robotics assisted TKA on blood loss in staged bilateral TKA performed with 1 week interval

30 patients who underwent robotics assisted TKA and 55 patients who under wen conventional MIS TKA were enrolled. All patients had staged bilateral TKA surgery with 1 week interval. Total blood loss, hidden blood loss, transfusion amount, and changes in Hg/Hct were evaluated and compraired at postoperative 3 day (1st TKA) and 10 day (2nd TKA).

There was no difference in sex, age, BMI, preoperative deformity, preoperative Hg/Hct in two groups. There was no difference in mean drop of Hg/Hct at postoperative 3 and 10 day. However, the time of normalization of Hg/ Hct was faster in Robotic group. The mean total blood loss was 651.1 mL at 1st TKA and 544.2 mL in robotic group. It was 674.7mL and 622.1mL in conventional group. The hidden blood loss was 475.8mL and 347.2mL in robotic group. It was 499.1mL and 448.3mL in conventional group($P<0.05$). Total transfusion amount was less in robotic group : (317mL at 1st TKA and 474mL at 2nd TKA in robotic group, 656.5 at 1st TKA and 804.8 at 2nd TKA in conventional group)

Robotics assisted TKA could reduce total blood loss, hidden blood loss and transfusion in 1 week interval stage bilateral TKA

Are Component Alignment and Biomechanics of Hip Resurfacing Improved by CT-Based Navigation?

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INTRODUCTION

Hip resurfacing arthroplasty (HRA) requires strict control of components alignment because their malalignment cause serious complications including femoral neck fracture, femoral component loosening and adverse reaction to metal debris (ARMDs). It was reported that cup inclination more than 45° related to ARMDs and excessive valgus placement of femoral components caused femoral neck fracture. HRA tends to maintain original hip biomechanics including leg length and offset, but their adjustment is still important. To achieve precise control of component alignment and reconstruct optimal hip biomechanics, we have made a CT-based plan prior to surgery and performed HRA using a CT-based navigation system. The purpose of this study was to access whether the use of CT-based navigation improved components alignment and hip biomechanics in HRA.

MATERIALS & METHODS

Between February 1998 and January 2017, unilateral HRA were performed in 13 hips by using CT-based navigation (N group) and 29 hips by using conventional jig without navigation system (C group) . All HRA were performed through posterolateral approach by surgeons with sufficient experience of HRA and navigation surgery. In N group, three-dimensional planning was performed using preoperative CT data, while two-dimensional planning was performed using hip anteroposterior radiographs in C group. The postoperative components alignment and hip biomechanics were evaluated using postoperative hip anteroposterior and Lauenstain radiographs. We evaluated the deviation of acetabular offset between the operative side and the non-operative side, postoperative leg length discrepancy (LLD), stem inclination, stem version, cup inclination, cup version and complications (Figure 1). Acetabular offset was defined as the distance between the vertical line passing through pubic symphysis and the femoral head center. Stem inclination was defined as the deviation between the postoperative stem-shaft angle and the preoperative neck-shaft angle on the AP radiographs. Stem version was defined as the angle between the femoral stem axis and the femoral neck axis in the Lauenstein view. We compared accuracy and precision of component alignment and hip biomechanics using Student's t-test and F-test, respectively. The values of $p < 0.05$ were considered to be statistically significant.

RESULTS

Implanted components alignment were showed Table 1. Stem inclination and cup inclination of C group was significantly larger than those of N group. Although all cases were no more than 45° of cup inclination in N group, there were 11 of 29 hips in C group. Stem version and cup anteversion were shown no significant difference between both groups. The deviation of Acetabular offset between both sides of hips were -0.3 ± 5.2 mm in N group and -1.8 ± 6.0 mm in C group. Postoperative LLD were 0 ± 2.7 mm in N group and 1.0 ± 6.4 mm in C group. There were no significant difference for acetabular offset and LLD between both groups. There were 1 case of femoral neck fracture and 1 case of cup loosening in C group.

CONCLUSION

The use of CT-based navigation system in HRA improved components alignment, but there was shown no significant improvement to reconstruct hip biomechanics.

Figures

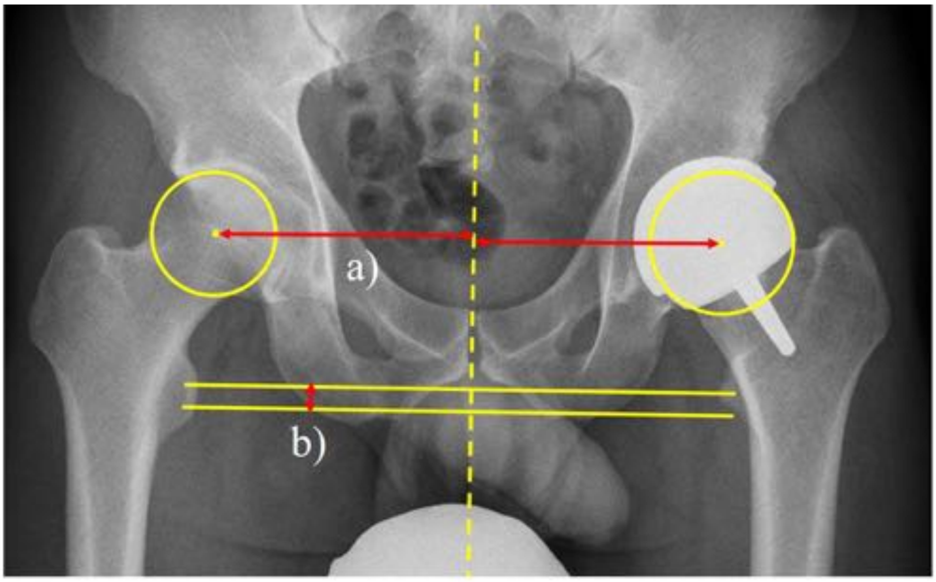

Figure 1 Postoperative radiographic evaluation

(a) Acetabular Offset (b) Leg Length Discrepancy (LLD)

Figure 1

Table 1 Implanted Components Alignment

Parameters	N group	C group	p value
Stem Inclination	3.9° (2.1°)	8.4° (6.0°)	0.04*
Stem Version	-1.7° (4.7°)	1.1° (8.1°)	0.5
Cup Inclination	40.1° (3.3°)	43.5° (7.0°)	0.04*
Cup Anteversion	13.2° (2.2°)	14.5° (3.2°)	0.07

Mean (SD)

Figure 2

#6029

Closed Reduction on a Rare Case of Resurfacing Dislocation Three Years Post Op.

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We report a rare case of Hip Resurfacing dislocation three years after a bilateral Hip Resurfacing in a very strong patient and show the maneuver to do a closed reduction on a film done at the surgical theatre under general anesthesia.

Hip resurfacing dislocation is a very rare entity described in the literature and more rare after three years. With conventional total hip replacement the dislocation rate is 2-5%. In the international literature the dislocation rate with resurfacing is 0.21%.

We describe a case of a 47 years old male patient who was submitted to a biltateral 54 X 60 mm Hip Resurfacing in November 16 th and 18th, 2011 (two separate days). He had a normal post op and returned to his work after six weeks and recreational activities after four months. Three years later, on November 8th, 2014 he did an extreme movement of hip flexion, adduction and internal rotation when he was gardening and planting a tree seedling suffering a left hip dislocation.

Hopefully we could reduce the dislocated hip in a closed manner in the following morning. Patient went home next day but on that same night had important abominal pain needing to return to hospital when numerous gallbladder stones where found being submitted to a total laparoscopic colecistectomy two days later. It was really a bad luck week.

Metal ions are still normal and patient is symptomless until today having returned to his recreational activities.

We will show in a movie the maneuver to do this closed reduction and hope by showing this maneuver that our colleagues do not have to do an open dislocation in the future in case they face a Hip Resurfacing dislocation.

References:

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2-Epidemiology of dislocation after total hip arthroplasty. Meek RM, Allan DB, McPhillips G et al. (2006) Clin Orthop Relat Res 447: 9–18

3-Dislocation as a rare complication of resurfacing of the hip joint. Case report and meta-analysis. Lieske S, et al. Unfallchirurg. 2008.

Figures

Figure 1

Figure 2

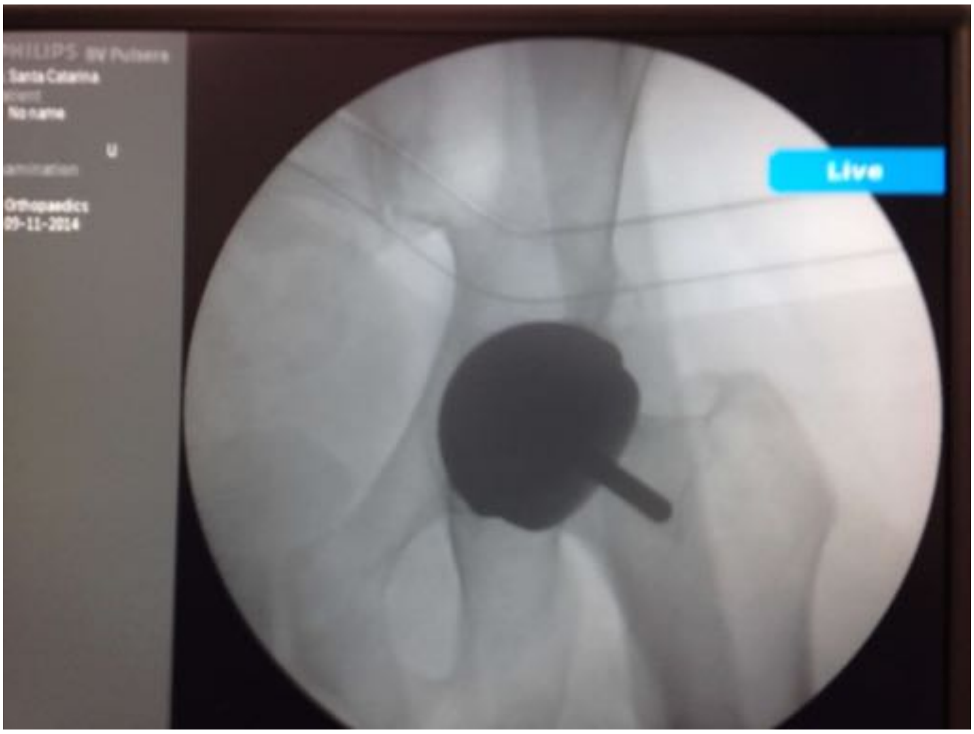

Figure 3

#5893

Compromise in Bone Density Results in Amplified Cement Layer Stress in Hip Resurfacing Arthroplasty

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As an alternative to total hip arthroplasty (THA), hip resurfacing arthroplasty (HRA) provides the advantage of retaining bone stock. However, femoral component loosening and femoral neck fracture continue to be leading causes of revision in HRA [1]. Surgical technique including cementation method and bone preparation [2], and patient selection are known to be important for fixation. This study was designed to understand if and to what extent compromise in bone quality and the presence of cysts in the proximal femur contribute to resurfacing component loosening.

A finite element (FE) model of a proximal femur was used to calculate the stress in the cement layer. Boundary conditions and contact patch locations over which joint load was applied, are shown in Fig. 1. Bone density to Young's modulus relationship [3] was used to calibrate the bone stiffness in the model using computed tomography. A contemporary resurfacing implant (BHR, Smith & Nephew) was used in the FE model. The effect of reduced bone quality (35% reduction relative to normal baseline; osteoporosis threshold [4]) and presence of cysts on stress in the bone cement layer was then assessed using the same FE model. The center of the cyst (a localized spherical cavity 1 cm in diameter) was located directly under the contact patch. Simulations were run with two locations of the center of the cyst, on the surface of the resected bone and 1 cm below it. The surface cyst was filled with bone cement, but the inner cyst was empty. The contact force and location for the model were obtained from instrumented implant studies [5]. Simulations were run representing the peak loads during two activities, jogging and stand-up from seated position.

While density reduction of the bone reduced the stress in the CoCr femoral head, the Von-Mises stress in the cement layer was amplified (Fig. 2). The peak Von-Mises stress in the cement layer under the contact patch increased more than six times for the jogging activity, and more than ten times for the stand-up activity, relative to values for normal bone density. The impact of cysts on the cement layer stress or the strain distributions in the bone were minimal.

The results show a greater risk of failure of the cement layer under conditions of reduced bone density. In contrast cement stresses and bone strains appeared to be relatively immune to a surface cyst filled with bone cement or an empty inner cyst. Contraindications of hip resurfacing include severe osteopenia and multiple cysts of the femoral head, however no strict or quantitative criteria exist to guide patient selection. Research similar to the one presented herein, maybe key to developing better patient selection criteria to reduce risk associated with compromised femoral head fixation.

1 S.-A. L. Ras Sørensen et al., 2016, Hip Int. 26(6).

2 H. C. Amstutz et al., 2007, J. Arthroplasty 22(4).
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Figures

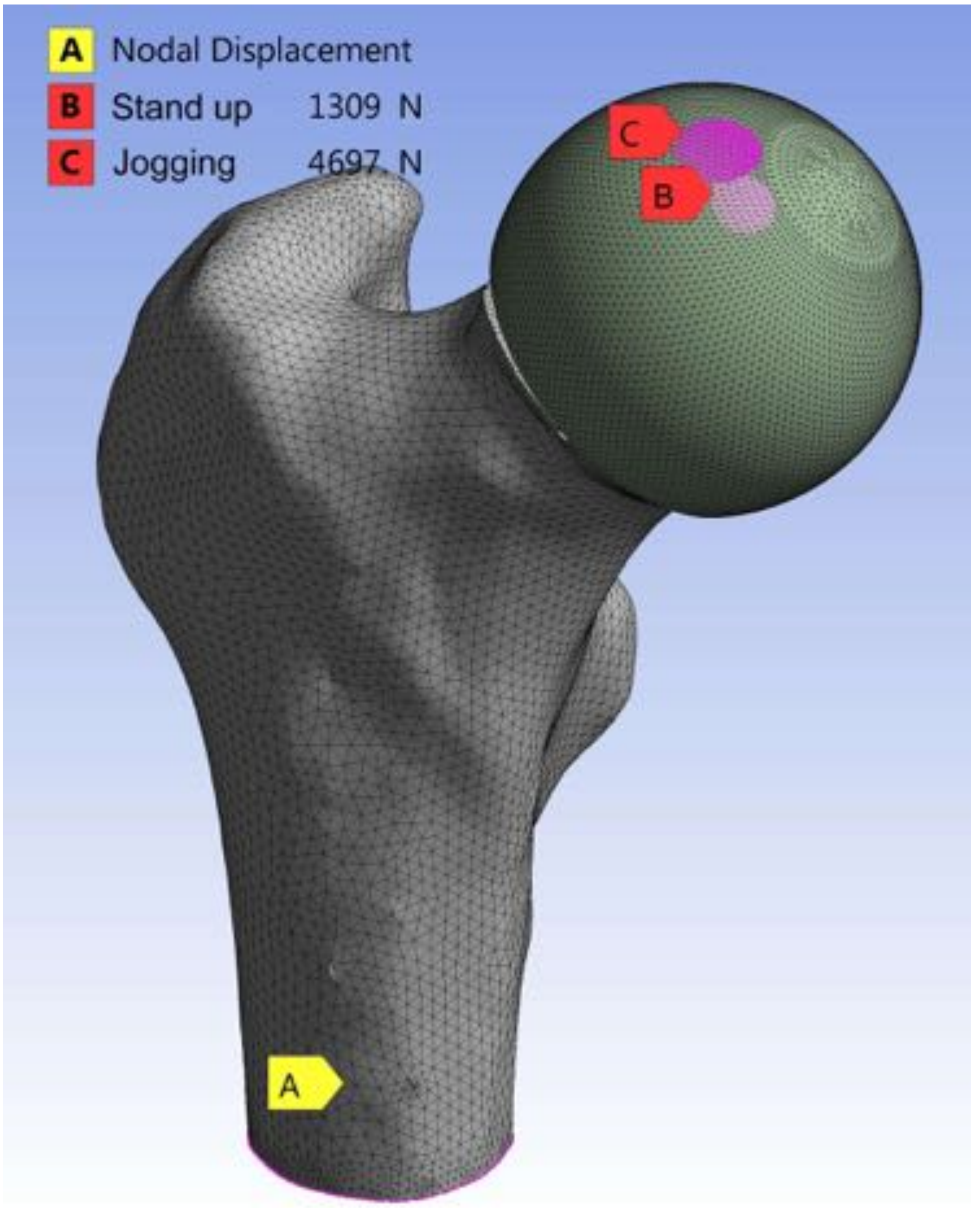

Figure 1: Finite Element mesh of the proximal femur with resurfacing implant. Boundary conditions are shown.

Figure 1

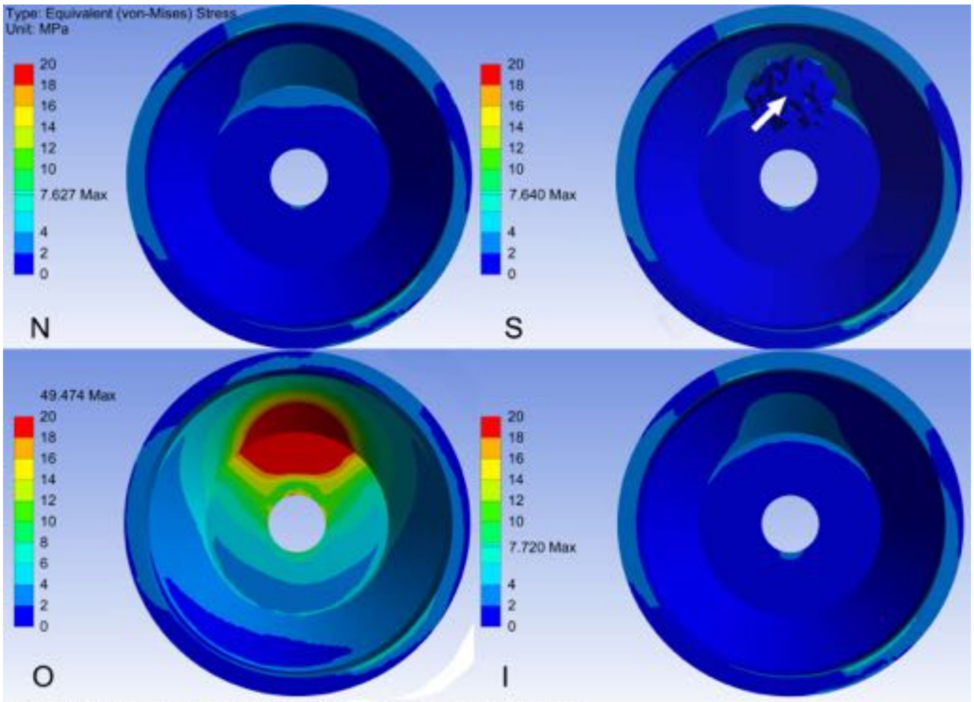

Figure 2: Stress under the cement mantle for the jogging activity. Clockwise from top left, normal bone (N), surface cyst filled with cement (S), inner empty cyst (I). Arrow shows surface cyst filled with cement.

Figure 2

#5948

Mortality After Hip Resurfacing vs. Total Hip Arthroplasty in Young Patients: A Single Surgeon Experience

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Introduction: Hip resurfacing arthroplasty (HRA) is an alternative to traditional total hip arthroplasty (THA) in young active patients. While comparative implant survival rates are well documented, there is a paucity of studies reporting the patient mortality rates associated with these procedures.The purpose of this study was to evaluate the mortality rates in patients age 55 years and younger who underwent HRA versus THA and to assess whether the type of operation was independently associated with mortality.

Patients and Methods: The database of a single high-volume surgeon was reviewed for all consecutive patients age 55 years and younger who underwent hip arthroplasty between 2002 and 2010. HRA became available in the United States in 2006. This yielded 504 patients who had undergone HRA from 2006 to 2010 and 124 patients who had undergone a THA. Patient characteristics were collected from the electronic medical record including age, gender, body mass index, Charleston comorbidity index, smoking status, and primary diagnosis **(Table 1)**. Mortality was determined through a combination of electronic chart reviews, patient phone calls, and online obituary searches. Univariate analysis was performed to identify a survival difference between the two cohorts. Multivariable Cox-Regression analyses were used to determine whether the type of operation was independently associated with mortality.

Results: The mean follow up for consecutive patients was 7 years (up to 11 years) in the HRA group and 8 years (up to 16 years) in the THA group. A total of 467 HRA patients (92%) and 105 THA patients (85%) were followed for a minimum of 5-years. There were 8 mortalities (1.6%) in the HRA cohort and 11 (8.9%) in the THA cohort, a statistically significant difference ($p<0.001$) on univariate analysis **(Figure 1)**.

Conclusion: We have demonstrated that patients under age 55 who undergo HRA have a significantly lower mortality rate than those undergoing THA. This is consistent with previously published large database studies [1,2]. Such studies typically analyze large heterogeneous populations of patients and surgeons. Our study uniquely examined only patients age 55 or younger from a single high-volume surgeon, and we primarily reviewed THA performed prior to the availability of HRA as a surgical option. Thus, surgeon selection bias was largely eliminated and patients were generally healthy. To our knowledge, this is the first single surgeon study comparing HRA and THA in terms of mortality.

References

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Figures

Figure 1.

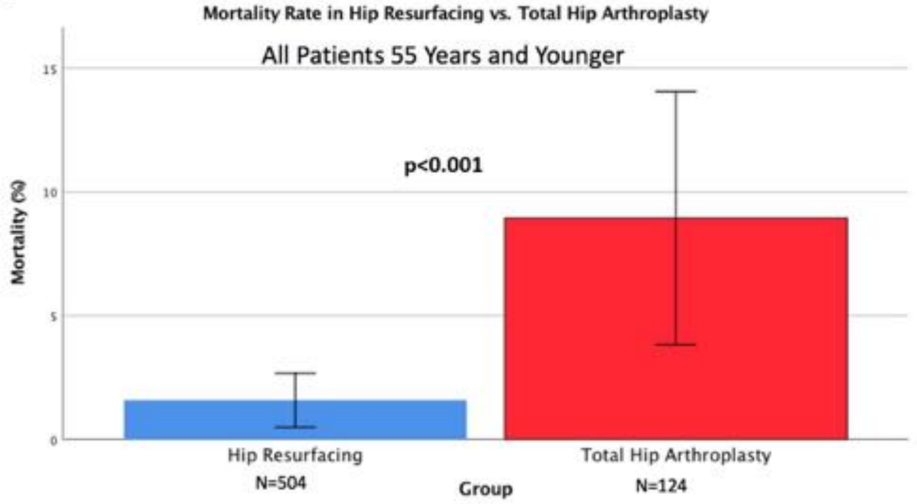

Figure 1

Table 1. Patient Demographics

	Resurfacing (n=504)	Standard THA (n=124)	p-value
Age in years (range)	48 (14-55)	47 (18-55)	0.007
Gender			0.021
Male	363 (71.9%)	76 (61.3%)	
Female	142 (28.1%)	48 (38.7%)	
Body mass index (range)	31.0 (18.4-63.3)	31.6 (18.7-60.5)	0.458
Tobacco smoker	58/480 (12.1%)	39/124 (31.5%)	<0.001
Charleston Comorbidity Index (IQR)	0 (0-0)	0 (0-1)	<0.001
Diagnosis			<0.001
Primary osteoarthritis	316 (62.6%)	68 (54.8%)	
Osteonecrosis	26 (5.1%)	27 (21.8%)	
Dysplasia	59 (11.7%)	10 (8.1%)	
Slipped Capital Femoral Epiphysis	79 (15.6%)	2 (1.6%)	
Other	25 (5.0%)	17 (13.7%)	

Figure 2

#6149

Performance of Ceramic Resurfacing Heads for Hip Arthroplasty - Component Strength.

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Introduction

A ceramic hip resurfacing system H1 (Embody, London, UK) made of zirconia toughened alumina (BIOLOX®delta, CeramTec, Plochingen, Germany) is under development to complement the benefits of using CoC by addition of bone-conserving advantages.

A thin-walled cementless anatomic head was designed to both maximally preserve the femoral epiphysis and to withstand high mechanical loads of post-operative situations. This paper presents results of mechanical testing substantiating the high strength of the H1 heads.

At the time no test standards were available. The test plan was developed based on literature (Dickinson et. al 2009, 2011) and existing standards (e.g. ISO/FDIS 11491) for THA. A resurfacing head usually experiences not only post-operative loading during service time but also intra-operative impaction forces. Therefore a series of static and dynamic tests for H1 heads have been developed and performed.

Material and Methods

To address intra-operative impaction of the H1 heads, a test setup was developed based on ISO/FDIS 11491: a defined weight falls onto a H1 head placed on a plastic support with defined impaction energy of about 15 Joule. To simulate a press-fit for cementless application, an interference between plastic supports and heads of 0.05mm-0.1mm were realized. After, H1 heads (n=3) were inspected for presence of cracks.

To cover post-operative high-demanding loads, samples (n=3) were subsequently fatigue tested. The load was applied at an angle of 45° with a peak force of 5.5kN (representing Jogging after Bergmann et. al 2001) for 20 million cycles at 20 Hz.

Lastly, the fatigue tested samples (n=3) were loaded to failure at 40° off-axis inclination as derived from Finite-Element-Analysis (FEA), representing the post-operative worst-case. The test was passed if the H1 head could be loaded to more than 22 kN (representing stumbling load of 11 kN after Bergmann et.al 2010 with safety factor of 2) without failure. Additionally, a static burst test (pre-fatigue), with n=5 samples, was conducted to compare pre- and post-fatigue strength (note: no press-fit was realized).

All tests were performed with the head size 40 mm.

Results

A single hit with 15 Joule was sufficient to get all heads fully seated on the plastic support. Neither fracture nor chip-off occurred at any of the heads. All three specimens were successfully loaded for the full fatigue loading regime without fracture or any other damage. After fatigue testing a residual burst strength of 26.97 kN (SD 0.81 kN) was achieved. For comparison an average static burst strength of 43.1 kN (SD 1.2 kN) was reached for heads not being pre-conditioned (no press-fit, no impact, no fatigue load).

Discussion

New tests were developed to evaluate the strength of new H1 heads under high demanding loads considering intra and postoperative situations. Test results demonstrate that H1 heads passed all criteria with not only high mechanical performance but also considerable safety margins of up to 2.5 times for Stumbling and 3.9 for Jogging. A clinical safety study with this H1 System is ongoing.

#5608

Determination of the Minimum Clearance of Ceramic Resurfacing Systems

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Introduction

Metallic resurfacing systems have been widely used until pseudotumors and ALTR have been clinically found and related to excessive wear of these metal-on-metal hip systems. Hence, surgeons widely abandoned the use of resurfacing systems. Meanwhile, there is a ceramic on ceramic (CoC) resurfacing system (Embody, London, UK) made of zirconia toughened alumina (BIOLOX®*delta*, CeramTec, Plochingen, Germany) in a clinical safety study. Even though conventional CoC hip systems are known for their excellent wear behavior, it has to be ensured that intraoperative and in-vivo deformations of the ceramic acetabular cup do not infringe the proper functionality of the system. The method of determining the minimum clearance of such a system will be presented here.

Materials and Methods

Combined experimental and numerical results were used to determine the deformation of the ceramic shell. In a cadaver lab, the resulting deformations after impaction of generic metal shells have been measured, see e.g. [1] for the method of measurement. The maximum deformation has been chosen for further calculation. Additionally, the stiffness of both generic metal and ceramic shells has been measured using ISO 7206-12. The deformation of the ceramic shells were then calculated by the equation

where u_c and u_m are the deformations of the ceramic and the metal shell, respectively, and K_m and K_c are the respective stiffnesses. Additionally, in a finite element simulation, the resulting deformation of the ceramic shell under in-vivo conditions was calculated and superposed with u_c. The resulting deformation was used as the minimum value of the clearance for the ceramic resurfacing system.

Results

The average value of the maximum deformation of the 8 generic metal shells was 177 µm (StD. 68 µm). Using the stiffness values for the ceramic and the metal shells, a maximum deformation for the ceramic shells (with the smallest and the largest outer diameter) were calculated to 56 µm and 74 µm, respectively. The superposition with the results from the FE studies led to deformation values of 69 µm (smallest shell) and 87 µm (largest shell), respectively. These values were chosen as the minimum values for the realization of the minimum clearance.

Discussion

The above described minimum clearance results from a worst-case scenario for the long-term deformation of the ceramic shells. The values from the experimental measurements were taken ten minutes after impaction in the cadaveric hips, when first relaxation already took place. Any other bone remodeling in the long-term, leading to further relaxation of the ceramic shell, has not been taken into account. The maximum deformations resulting from the numerical investigations have been superposed to the experimental values, assuming that both maximum deformations are acting in the same direction. In reality, this is most likely not the case because the line-of-action of the in-vivo forces acting on the hip are not collinear with the direction where the maximum deformation during intra-operative impaction takes place. Additionally, the experimentally chosen underreaming (1 mm) can also be considered as a worst-case. Hence, the calculated minimum clearances are representing the maximal deformation that in the long-term may take place in-vivo.

References

[1] Dold et al., Proc Inst Mech Eng H. 2014 Aug;228(8):781-6

#6005

Deformation and Temperature Changes During Femoral Implantation in a Novel Ceramic and a Standard Metal Hip Resurfacing

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INTRODUCTION

Experience with Metal on Metal (MoM) hip resurfacing devices has shown adequate cementation of the femoral head is critical for implant survival. Bone necrosis can be caused by the temperature change in the peri-prosthetic bone whilst the cement cures during implantation. This can lead to implant loosening, head/neck fracture and implant failure. During the implantation it is known that implants change shape potentially altering joint clearance and causing loosening. Given the history of Metal on Metal implant failure due adverse tissue reactions from Cobalt and Chromium particles we sought to test a novel Ceramic on Ceramic (CoC) bearing which may mitigate such problems.

AIM

We set out to compare the behaviour of a novel ceramic femoral head component to a standard metal component in a hip resurfacing system after cemented implantation in a physiological warmed cadaveric model.

- Our first aim was to perform heat transfer analysis: To document time to, and extent of, maximum temperature change on the metal/ceramic surface and inside the resurfaced femoral head bone.
- Our second aim was to perform a dimensional analysis: To document any resulting deformation in the metal/ceramic femoral head bearing diameter during cementation.

METHODS

Femurs were removed from four fresh frozen cadavers and placed into a vice. One surgeon with extensive experience in hip resurfacing surgery (JH) prepared all the femoral heads for implantation. Cadaveric warming was performed using a thermostatic silicone heating element to achieve near physiological conditions (28-32°C).

The femur components were then implanted onto the femur head using Simplex P (Stryker) low viscosity bone cement. We used four ceramic (ReCerf™) and four metal implants (ADEPT®) of equal and varying size. (2 x (42mm, 46mm, 48mm, 50mm).

Temperature change was measured using a thermometer probe placed into femur neck and head from the lateral side with position check using an image intensifier. Implant surface temperature was measured using a calibrated infrared thermometer at a standard 30cm distance. Head bearing surface diameter was measured using a micro-meter. Measurements were taken 2mins pre-implantation and sequentially at 1, 5, 10, 15, 20, 25 and 30 minutes after implantation.

RESULTS

The bone temperature change for both metal and ceramic implants fell after implantation and then increased (Fig. 1). The implant surface temperature increased and then stabilised for both implants (Fig. 3). There was no significant difference in the bone or surface temperature change between metal and ceramic implants. The bearing surface diameter change was greater in the metal implants (Fig. 2) although this was not significant. All implants returned to within one µm of initial surface diameter at 30 minutes.

CONCLUSIONS

The femoral head component of a ceramic resurfacing has similar properties for surface temperature change following implantation to conventional MOM resurfacing. The periprosthetic bone is not at risk of significant heat necrosis during cementation (max temp 32°C). The deformation following implantation was similar for both metal and ceramic components. All implants returned to near initial diameter.

The deformation and temperature changes following implantation of a ceramic resurfacing are similar to a metal implant.

Figures

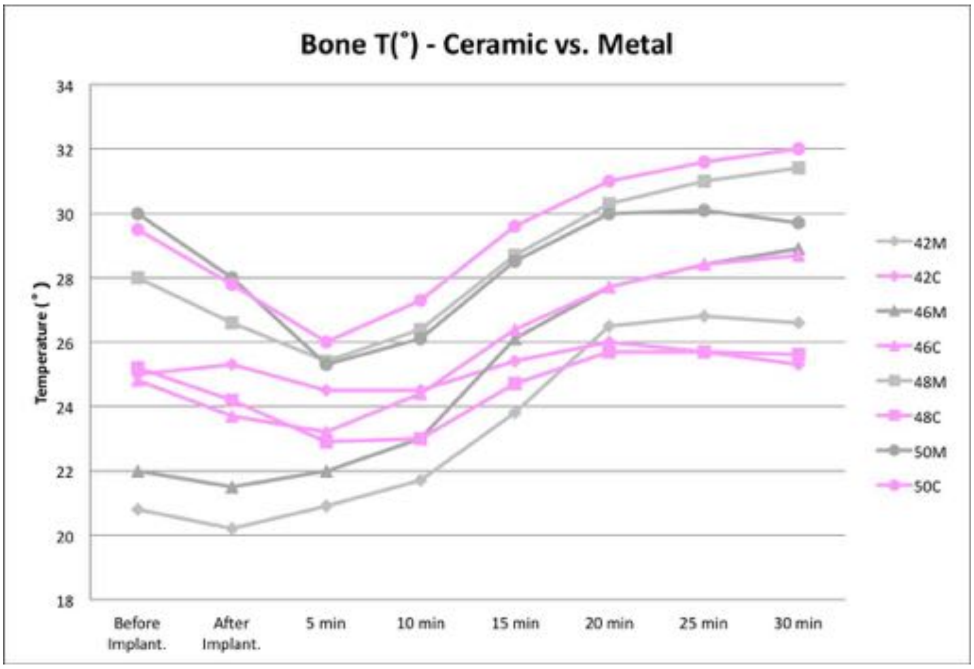

Figure 1

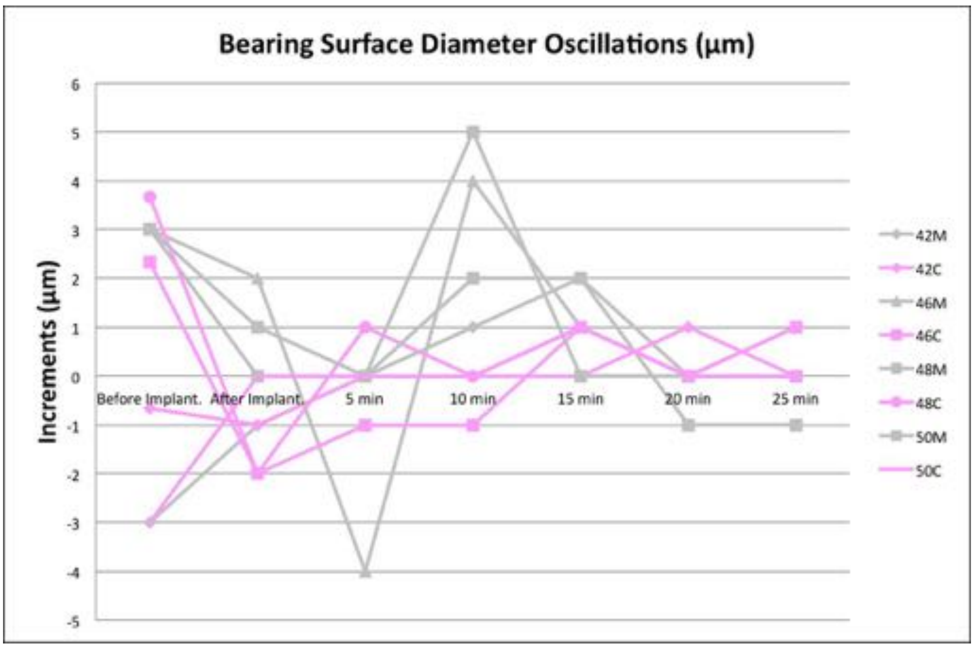

Figure 2

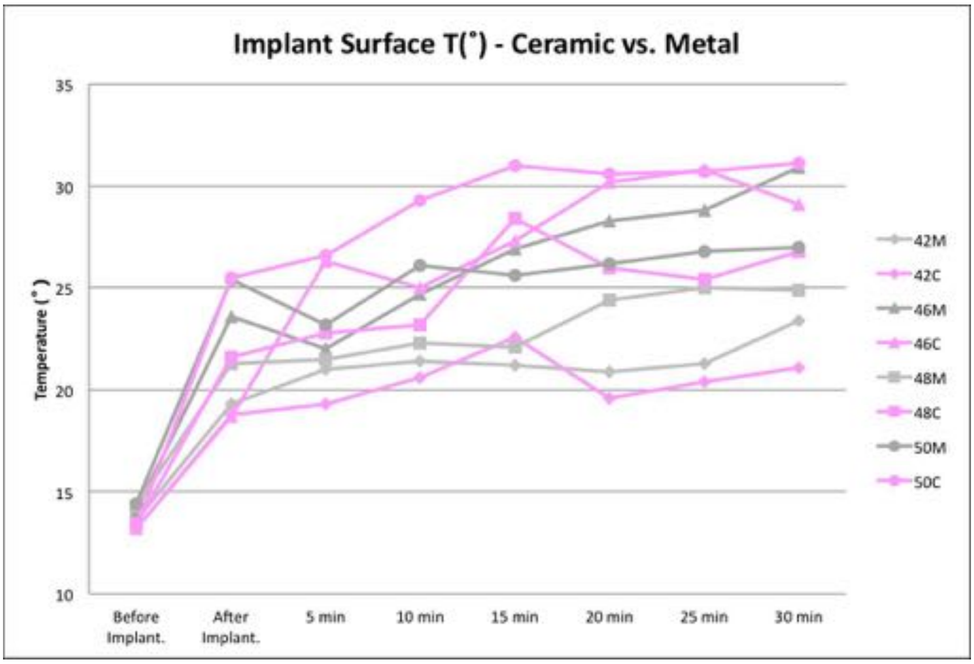

Figure 3

#6119

The Influence of Stem Occupation Ratio on Stem Subsidence and Cement Creep. -a Biomechanical Study Using a Collarless Polished Tapered Stem-

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[Introduction]

We had reported that stem subsidence showed a strong positive correlation to the thickness of cement mantle, and effective radial cement creep was seen in thin cement mantle in an experimental study using collarless polished tapered (CPT, ZimmerBiomet, USA) stem. However, the cement mantle was measured two-dimensional and have not analyzed as volumetric comparison. The aim of this study is to analyze the influence of stem occupation ratio on stem subsidence and cement creep as a three-dimensional study.

[Methods]

A cemented stem biomechanical model was used for this study with a CPT stem into composite femur. Three sizes of CPT stems (No. 1, No. 2 and No. 3) and one size composite femur were prepared for this study. We inserted two stems for each size, for a total of six stems. Composite femurs were reamed with a No. 3 rasp, and various size of stem was fixed with cement in each composite femur to make a various thicknesses of cement mantle. A tantalum marker ball was adhered to the tip of stem to measure stem subsidence. Two to three tantalum marker balls were injected into the cement in each femur before cement was hardened.(Figure 1) 1-Hz dynamic load applied to the stems for half a-million cycles. Each 16 hours of loading was followed by 8 hours without loading.(Figure 2) We used micro-CT before and after loading to measure the movement of the tantalum balls in three dimensions. We also reconstructed a stem and cement three-dimensional model.(Figure 3) And we analyzed occupation ratio of stem (OR) in the proximal femoral canal portion where the tantalum marker balls exist. The OR was defined as the volume ratio of stem volume to stem and cement volume.

[Results] The mean of stem subsidence was 0.35mm (0.12 to 0.58mm). The mean of OR was 62.0% (49.2 to 69.5%). Stem subsidence showed a significantly strong negative correlation to the OR ($r= -0.9$, $P=0.01$). We were able to detect a total of 13 balls in the cement for the 6 stems. The horizontal/perpendicular migration ratio for the tantalum balls showed a significant positive correlation to the OR. The subsidence rate (ratio of stem subsidence to ball subsistence) showed a significant negative correlation to the OR. The effective radial cement creep was also detected when the OR was more than 65%.

[Conclusions] Stem and cement subsidence was more commonly associated with a low OR in this study using CPT stems.

Figures

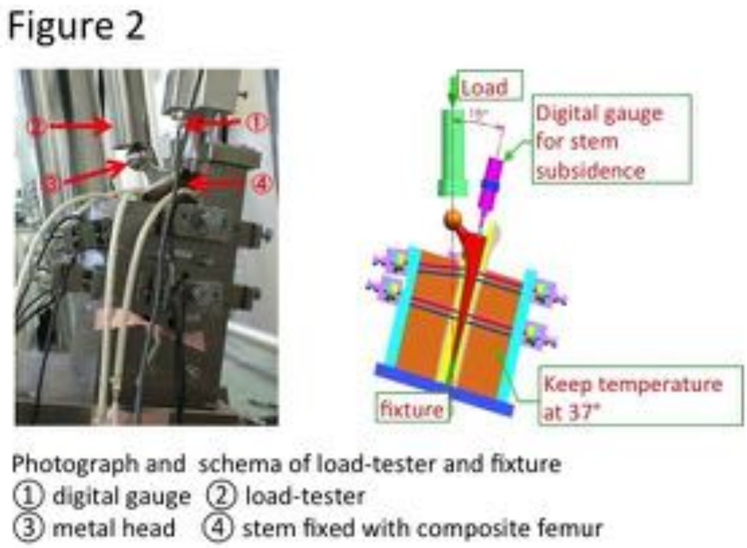

Figure 1

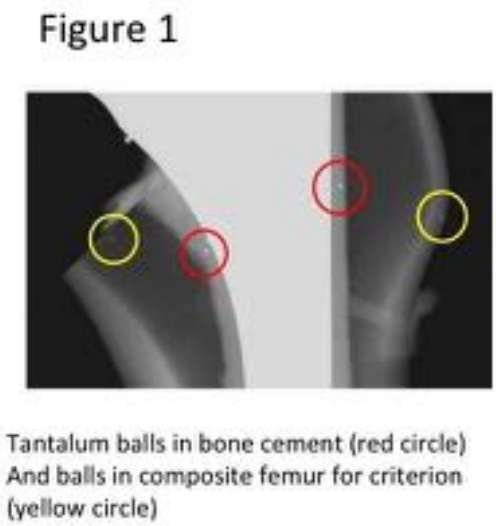

Figure 2

Figure 3
Tree-dimensional model of cement and stem

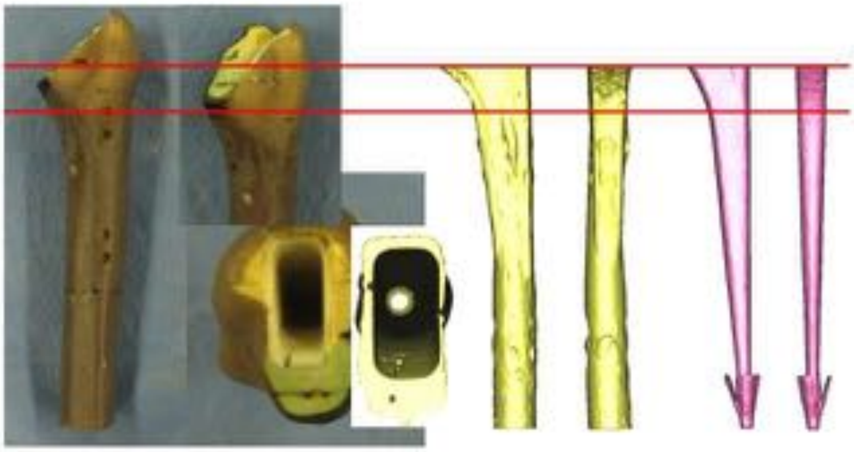

Figure 3

#6069

The Importance of Considering Dynamic Strain in Bone During Seating of Cementless Components

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Incidence of intraoperative fracture during cementless Total Hip Arthroplasty (THA) is increasing. This is attributed to factors such as an increase in revision procedures and the favour of cementless fixation. Intraoperative fractures often occur during the seating of cementless components. A surgical mallet and introducer are used to generate the large impaction forces necessary to seat the component, sometimes leading to excessive hoop strain in the bone. The mechanisms of bone strain during impaction are complex and occur over very short timeframes. For this reason experimental and simulation models often focus on strain shortly after the implant is introduced, or seat it quasi-statically. This may not produce a realistic representation of the magnitude of strain in the bone and dangerously under-represent fracture risk.

This in-vitro study seeks to determine whether strain induced during impaction is similar both during the strike (dynamic strain) and shortly after the strike has occurred (post-strike strain). It is also asked whether post-strike strain is a reliable predictor of dynamic strain.

A custom drop tower was used to seat acetabular components in 45 sawbones models (Figure 1). Ten strikes were used to seat each cup. 3 strike velocities (1.5 m/s, 2.75m/s, 4m/s) and 3 impact masses (600g, 1.2kg, 1.8kg) were chosen to represent 9 different surgical scenarios. Two strain gages per sawbone were mounted on the surface of the block, 2mm from the rim of the cavity (Figure 1). Strain data was acquired at 50khz. Each strain trace was then analysed to determine the peak dynamic strain during mallet strike and the static strain post-strike.

Figure 2 shows a typical strain gauge trace during a seating strike. An initial pre-strike strain is followed by a larger dynamic peak as the implant is progressed into the bone cavity. Strain subsequently settles at a lower value post-strike. Over the 450 strikes conducted dynamic strain was on average 3.39 times larger than post-strike strain. A statistically significant linear relationship was observed between the two data sets (adjusted R^2=0.391, p<0.005). This indicates that, for a known scenario, post-strike strain can be used as an indicator for dynamic peak strain. However when only the maximum dynamic and post-strike strains were taken from across the 10 strikes used to seat the implant, the relationship between the two strains was not significant (R^2=0.300, p=0.73, Figure 3). This may be due to the fact that the two maximums did not often occur on the same strike. On average, max dynamic strain occurred 1.7 strikes after max post-strike strain.

We conclude that peak dynamic strain is much larger than the strain immediately post-strike in a synthetic bone model. Figure 3 also shows that post-strike strain is not a good predictor of dynamic strain when the max strain during any strike to seat the component is considered, or variables (such as mallet mass or velocity) are changed. It is important to consider dynamic strain in bone as well as post-strike strain in experimental or simulated bone models to ensure the most reliable prediction of fracture.

Figures

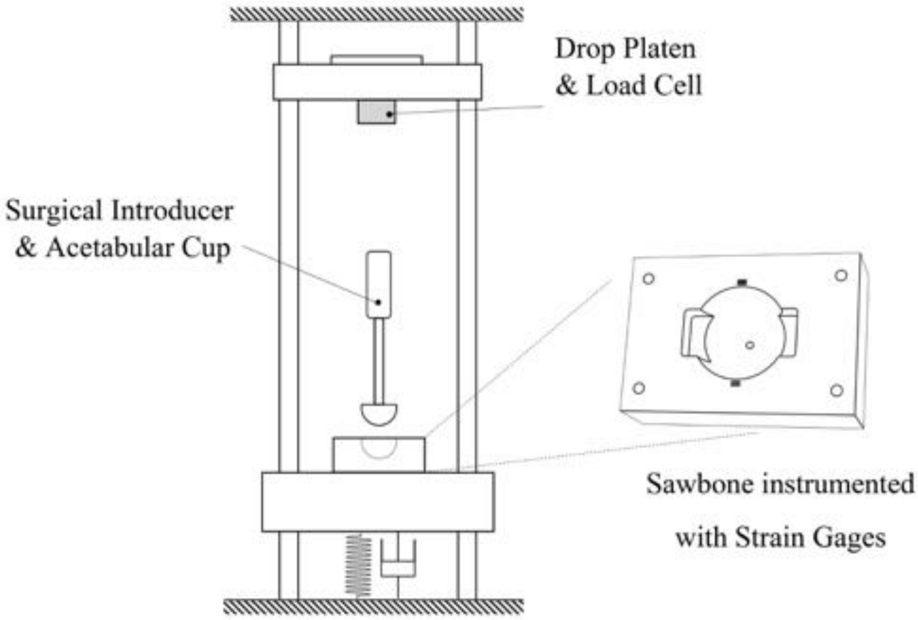

Figure 1: Experimental Setup

Figure 1

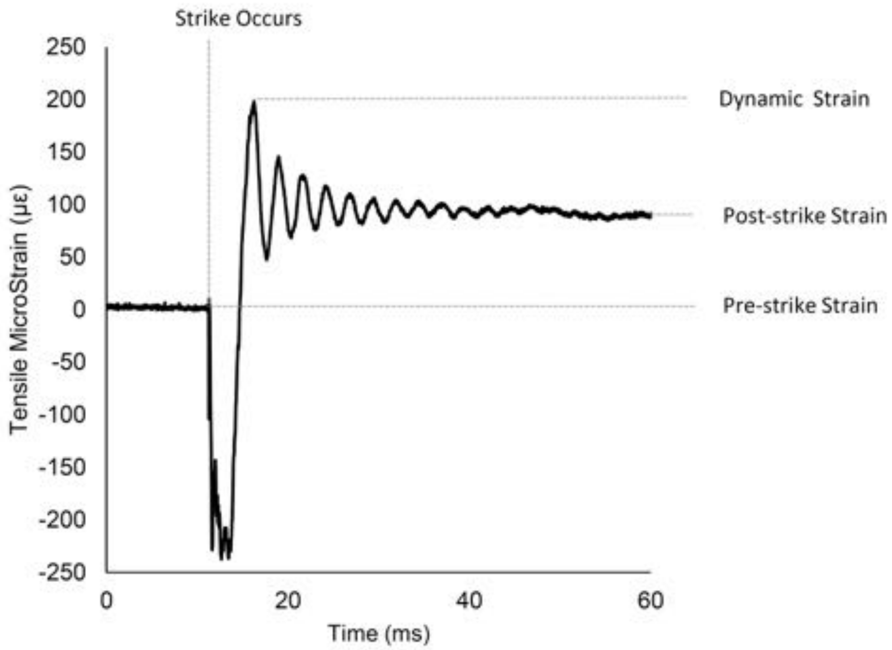

Figure 2: Example Strain Gauge Trace

Figure 2

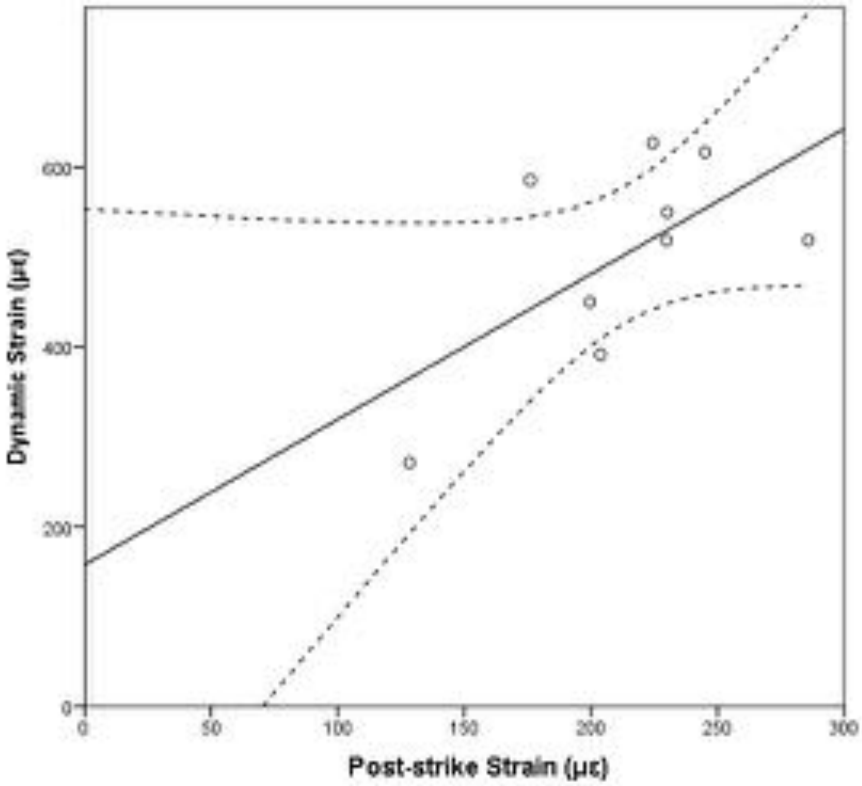

Figure 3: Maximum Dynamic and Post-Strike Strain taken during 10 Seating Strikes

Figure 3

#6121

Affects of Proximal Hydroxyapatite Coating in a Tapered, Rectangular Titanium Stem / ZweymÃ¼Ller Type

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Introduction: A long-term result of the original Zweymüller stem is already satisfied and bone preserved type of similar stem (SL-Plus MIA) is also reported comfortable clinical results. On the other hand, radiolucent line (RLL) in proximal part of the stem is popular findings in radiograms. These appearances are not affected on fixation of the stem but are confused as loosening and stems were revised occasionally. Therefore, proximal hydroxyapatite coating stem (SL-Plus MIA HA) were introduced and expected changes of osseous response around the stem. In this study, we investigated clinical results and radiological findings between SL-Plus MIA and SL-Plus MIA HA stems.

Materials and methods: From October 2012, SL-Plus MIA stem was used in 64 hips of 58 patients including four males and 54 females. The diagnoses were osteoarthritis in 56 hips and rheumatoid arthritis in two hips and others. Average age of surgery was 70.5 + 7.9 years old and the follow-up period was 61.0 months. From November 2014, SL-Plus MIA HA stem was used in 60 hips of 53 patients including five males and 48 females. The diagnoses were osteoarthritis in 53 hips and osteonecrosis in three hips and others. Average age of surgery was 70.0 + 9.9 years old and the follow-up period was 31.3 months. Clinical results were evaluated by Harris hip score (HHS) and radiological assessments were used by fixation / stability score (FSS) according to Engh, subsidence (more than 2 mm), grade of stress shielding (SS), radiolucent line (RLL) and cortical hypertrophy (CH).

Results: HHS was 44.3 points before surgery and 89.5 points at follow-up in SL-Plus MIA. It was 41.5 points before surgery and 88.1 points at follow-up in SL-Plus MIA HA. There were no differences between two groups. FFS was 18.4 points in MIA group and it was 21.3 points in MIA HA group. RLLs in proximal femur of the MIA group were 31 hips (48.4%) in zone 1 and 14 hips (21.9%) in zone 7 and RLLs of MIA HA group were 3 hips (5%) in zone 1 and 2 hips (3.3%) in zone 7. Cortical hypertrophy in distal femur was 24 hips (37.5%) in MIA group and it was 18 hips (30%) in MIA HA group. There was no subsidence more than 2 mm in both groups. Stress Shielding were also no significant differences between two groups.

Conclusion: Proximal hydroxyapatite coating in SL-Plus MIA could reduce the appearance of RLLs, but clinical results and other radiological findings were similar therefore concepts of the stems were kept between both stems.

#6086

The Bone Ingrowth of a Silver Oxide-Containing Hydroxyapatite Coating Antibacterial Cementless Acetabular Socket.

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ã€Introductionã€‘

Tight fixation between bone and implant materials is of great importance for a successful outcome of procedures such as cementless total hip arthroplasty (THA). The initial fixation by the press fit and the final fixation by the bone ingrowth is important in cementless acetabular socket. Coating with bioactive ceramics such as hydroxyapatite (HA) is a popular method for facilitating direct bonding to living bone [1,2]. HA coating of cementless acetabular socket surface is useful for early bone ingrowth and good bone ingrowth of the HA coating cementless acetabular socket and long-term results are reported [3-5].

The silver oxide-containing hydroxyapatite (Ag-HA) coating hip prosthesis (AG PROTEX®: KYOCER, Osaka, Japan) is world's first antibacterial cementless implant that had both osteoconductivity of the HA and antibacterial activity of silver [6] (Fig.-1). The Ag-HA coating was shown to have good osteoconductivity and new bone formation in vitro and in vivo study, and thereby contributes to sufficient anchorage strength of implants [7,8]. Furthermore, the good initial stability of the Ag-HA coating hip prosthesis with radiographic evaluation is shown in clinical study [6]. However, the osteoconductivity and histologic bone ingrowth of the Ag-HA coating hip prosthesis has not been yet confirmed in clinical study.

ã€Materials & Methodsã€‘

In this study, we analyzed bone ingrowth using two silver oxide-containing hydroxyapatite coating socket which were removed in revision total hip arthroplasty for the recurrent dislocation. The histomorphometrical analysis was performed by Scanning Electron Microscope (SEM) connected to a CCD camera and the elemental analysis was performed by Energy dispersive elemental spectrometry (EDS).

ã€Resultã€‘

A white structure thought to be the osseous tissue attached to the retrieved socket surface (Fig.-2), and histological bone ingrowth in silver oxide-containing hydroxyapatite coating of the socket was confirmed with SEM (Fig.-3). In addition, silver was confirmed in silver oxide-containing hydroxyapatite coating using elemental analysis by EDS.

ã€Conclusionã€‘

As well as conventional hydroxyapatite coating cementless acetabular socket,the silver oxide-containing hydroxyapatite coating socket presented histologically good bone ingrowth in clinical study.

Figures

Figure 1

Figure 2

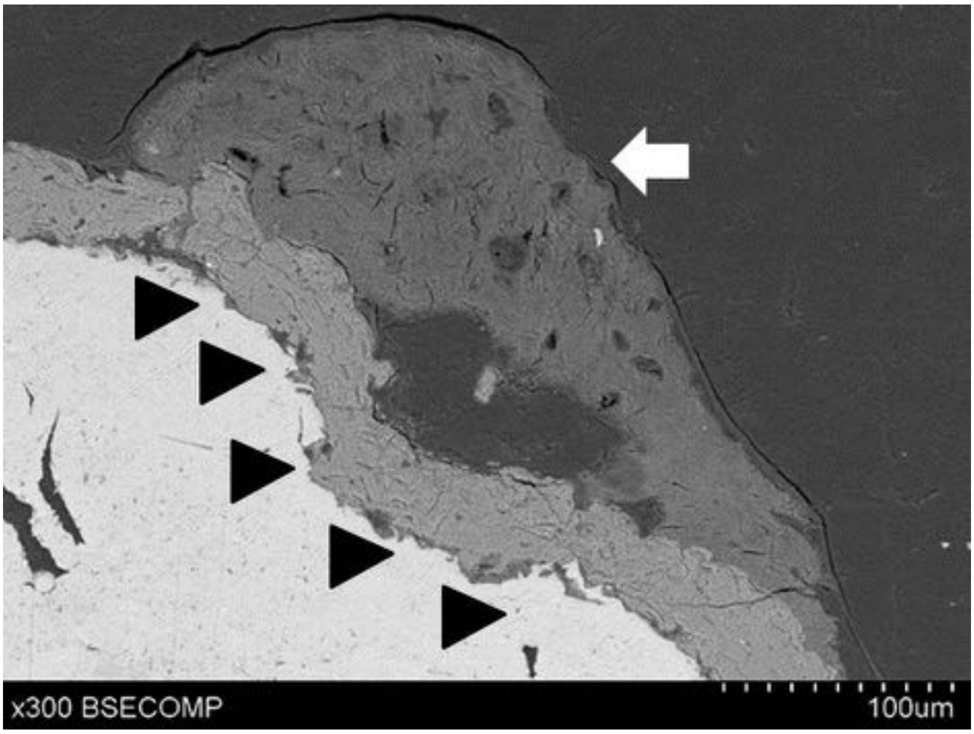

Figure 3

#5763

Sensitivity of FEA Predicted Micromotion to Implant-Bone Contact Angle in a Wedge Stem

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Blade or wedge stems with narrow anterior posterior dimensions have flexible insertion positioning, but also have a greater reliance on the surgeon to achieve stable three point fixation. Because the natural shape of the femoral metaphysis funnels from the epiphysis to the diaphysis, a wedged shape implant that simultaneously contacts both medial and lateral sides of the cortical bone has a high resistance to subsidence. Further, by matching the implant shape to the cortical bone along the length of the contact region, rotational stability can be improved. This study examined the sensitivity of implant micromotion to the angle between the contact segment of the implant and the femur using finite element analysis. The contact segment angle is illustrated as L and M in Figure 1.

A statistical shape model was used to design a concept wedge shape that would fill the medial – lateral width of the distal metaphysis inferior to the lesser trochanter. The nominal value for the contact segment angles were chosen to fit the range of femur shapes of the metaphyseal medial and lateral curves from the shape model. Variations of the concept with L and M increased by 2° and decreased by 2° were also evaluated. A similarly sized commercially available blade stem used to establish baseline micromotion.

The FEA model used linear tetrahedral meshing (Figure 2) and all materials were treated as linear orthotropic. Frictionless sliding contact was modeled with line-to-line fit between implant and bone surfaces. Micromotion predictions were previously validated using DIC measurements in cadaveric tissue. Two loading conditions were simulated: ISO 7206 10/9 loading and intraoperative torsion about the implant neck axis.

Micromotion was calculated as the difference in displacement along stem axis “vertical” and perpendicular to stem axis “transverse”. Increasing the contact segment angle resulted in generally minor micromotion variations. However, decreasing the contact segment angle resulted in large increases in micromotion though the micromotion was still generally less than the reference stem except for transverse motion at the distal stem.

Table 1. Micromotion predictions (mm).

Stem design	ISO 10/9 transverse	ISO10/9 vertical	Torsion transverse	Torsion vertical
baseline	*0.336*	*1.063*	*0.428*	*-1.040*
nominal	0.147	0.516	0.129	-0.193
+ 2°	0.165	0.465	0.131	-0.194
- 2°	0.281	0.976	0.153	-0.194

Placement of the stem is a critical consideration for evaluating stability. By filling the distal metaphysis, the concept stem was able to engage a greater area of cortical bone, including bone that was oriented better to resist rotational motion.

Figures

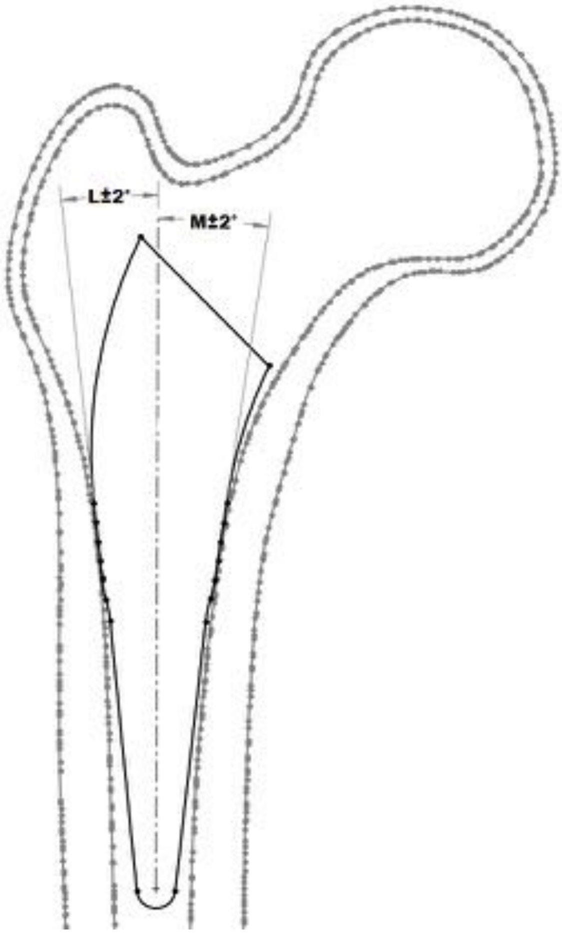

Figure 1

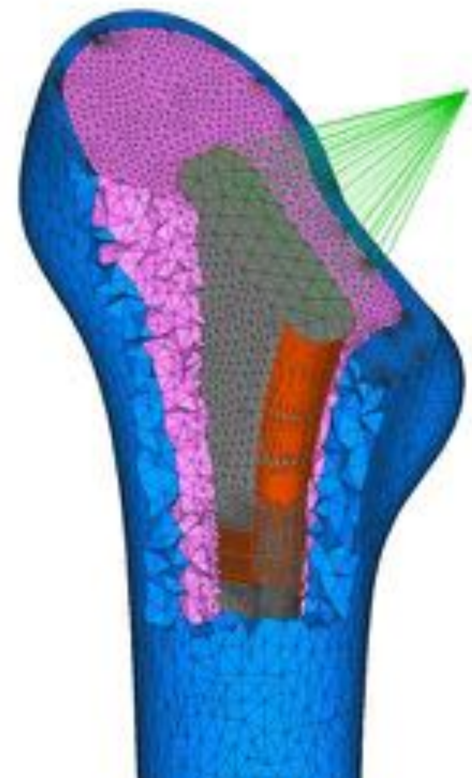

Figure 2

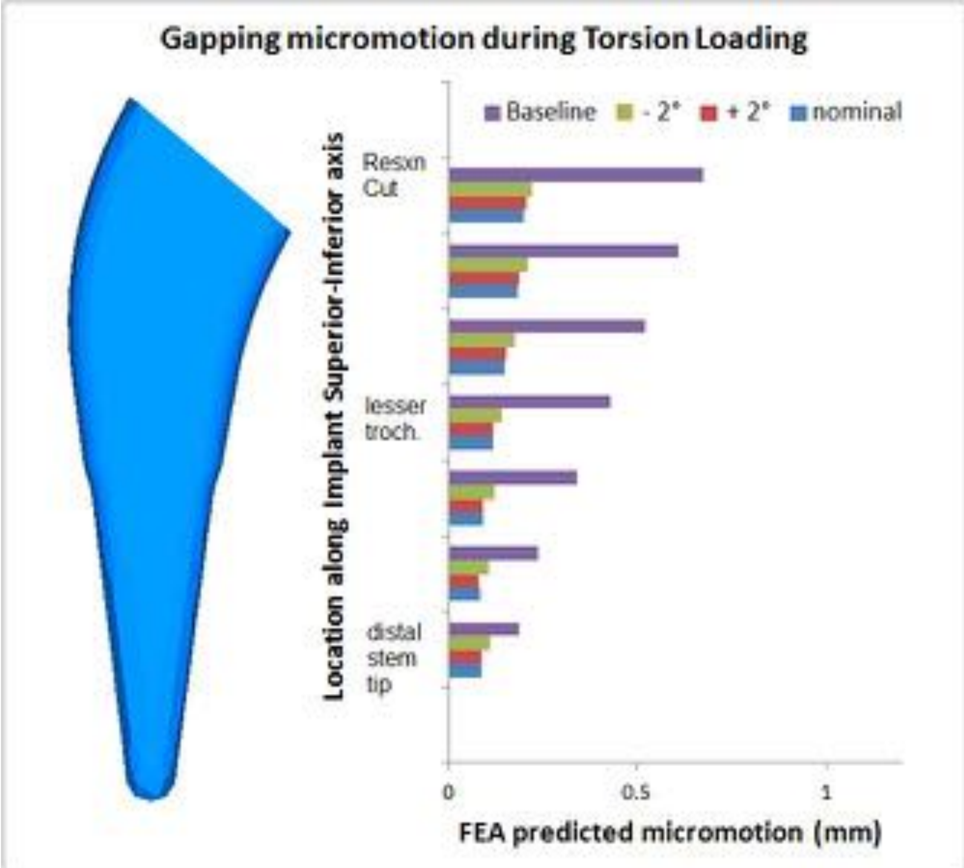
Gapping micromotion during Torsion Loading
Baseline
- 2°
+ 2°
nominal
Resxn Cut
lesser troch.
distal stem tip
Location along Implant Superior-Inferior axis
0
0.5
1
FEA predicted micromotion (mm)

Figure 3

#5638

Inferior Extended Fixation Using Porous Metal Augments in Acetabular Reconstruction During Revision Total Hip Arthroplasty

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Abstract

Background: Failed ingrowth and subsequent separation of revision acetabular components from the inferior hemi-pelvis constitutes a primary mode of failure in revision total hip arthroplasty (THA).Few studies have highlighted other techniques than multiple screws and an ischial flange or hook of cages to reinforce the inferior fixation of the acetabular components, nor did any authors report the use of porous metal augments in the ischium and/or pubis to reinforce inferior fixation of the acetabular cup.The aims of this study were to introduce the concept of inferior extended fixation into the ischium and/or pubis during revision total hip arthroplasty [Fig. 2], and to determine the early clinical outcomes and the radiographic outcomes of hips revised with inferior extended fixation.

Methods: Patients who underwent revision THA utilizing the surgical technique of inferior extended fixation with porous metal augments secured in the ischium and/or pubis in a single institution from 2014 to 2016 were reviewed. 16 patients were included based on the criteria of minimum 18 months clinical and radiographic follow-up. No patients were lost to follow-up. The median duration of follow-up for the overall population was 31.43 months. The patients' clinical results were assessed using the Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index and Short form (SF)-12 score and satisfaction level based on a scale with five levels at each office visit. All inpatient and outpatient records were examined for complications, including infection, intraoperative fracture, dislocation, postoperative nerve palsy, hematoma, wound complication and/or any subsequent reoperation(s). The vertical and horizontal distances of the center of rotation to the anatomic femoral head and the inclination and anteversion angle of the cup were measured on the preoperative and postoperative radiographs. All the postoperative plain radiographs were reviewed to assess the stability of the components.

.

Results: At the most recent follow-up, 11 (68.8%) patients rated their satisfaction level as "very satisfied" and 4 (25.0%) were "satisfied." The median HHS, as well as the SF-12 physical and mental components improved significantly and the WOMAC global score decreased significantly at the latest follow-up (pï¼œ0.001). No intraoperative or postoperative complications were identified. All constructs were considered to have obtained bone ingrowth fixation. The median vertical distance between the latest postoperative center of rotation to the anatomic center of the femoral head improved from 14.7±10.05 mm preoperatively to 6.77±9.14 mm at final follow-up (p=0.002). The median horizontal distance between the latest postoperative center of rotation to the anatomic center of femoral head improved from 6.3±12.07 mm laterally preoperatively to 2.18±6.98 mm medially at the most recent follow-up (p=0.013) postoperatively. The median acetabular cup abduction angle improved from 55.04°±10.11° preoperatively to 44.43°± 5.73° at the most recent follow-up postoperatively (p=0.001). However, there was no difference in the median cup anteversion angles preoperatively (9.15°±5.36°) to

postoperatively (9.66°±3.97°) (P=0.535).

Conclusions: Early follow-up of patients reconstructed with porous metal augments using the inferior extended fixation surgical technique demonstrated satisfactory clinical outcomes, restoration of the center of rotation and adequate biological fixation.

Figures

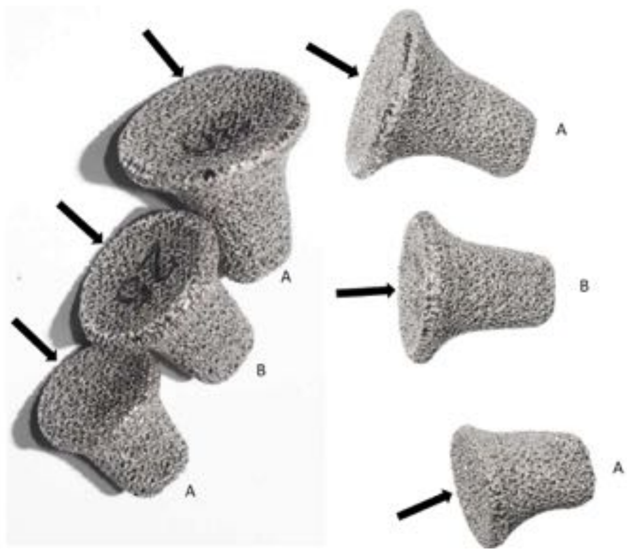

Figure 1

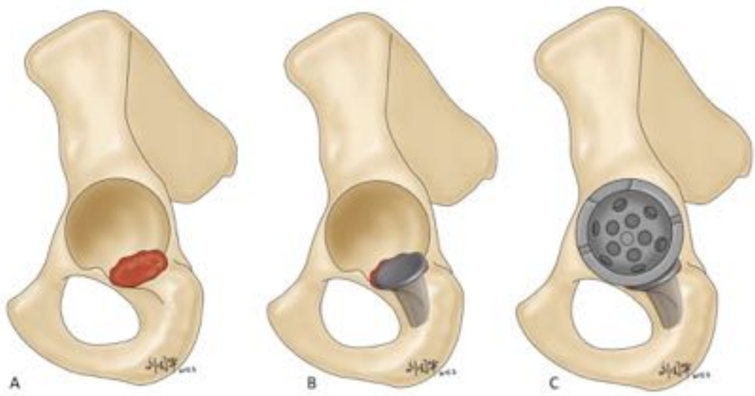

Figure 2

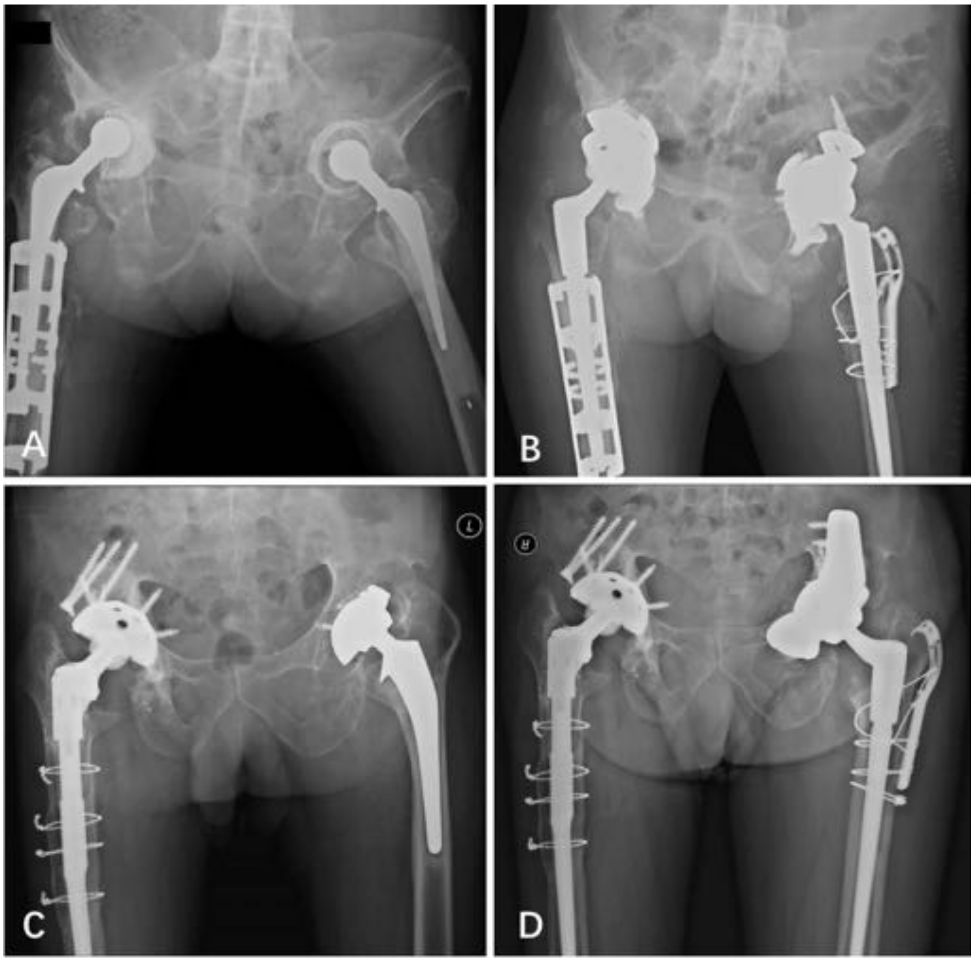

Figure 3

#5879

Acetabular Components With or Without Screws in Cementless Short Stem Total Hip Arthroplasty

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Cementless acetabular cups can be implanted with or without screw. While some studies have reported that the additional screw improves stability, others have mentioned that the press-fit implanted no-screw components have produced similar results with the screw fixation systems.

The aim of this study; to compare the operation time, blood loss and early outcomes of acetabular components with and without the screws in cementless short stem total hip arthroplasty.

Materials and methods

We formed two groups. Group A; 53 patients who underwent cementless acetabular component with short femoral stem and without screw (Figure 1). Group B; 48 patients who underwent cementless acetabular component with short femoral stem and with one, two or three screw (Figure 2). At least two-year follow-up patients were evaluated to work. A posterior approach was used in all surgical procedures by two experienced surgeon. Patients began to walk with full weight bearing at 3th week after surgery.

Demographic data (Figure 3), operation time, intra- and postoperative blood loss volume, follow-up clinical score, osteolysis and revision rate were recorded.

We used tranexamic acid in both grous before the operation as Morrison et al.

The postoperative blood loss was calculated by the volume of drainage. Harris hip scores (HHS) were recorded at preoperative and postoperative. Radiolucent lines, osteolytic lesions more than 3 mm in diameter and bone loss were recorded on radiographs of the patients at 3 acetabular regions.

Results

While the mean operation time was 89,4 min (72-115), in the group A, it was 96,7

min (81-120) in the group B. The mean postoperative drainage volume was 123.3 mL (91-165) in the Group A and 153.3 mL (93-180) in the group B. Respectively in group A and group B preoperative HHS is 46,44 and postoperative 94,94. We revised two patients in each groups. In group A; one of them is infection and the other is periprosthetic fracture. In group B; infection and dislocation. One patient in screw group had osteolytic lesions around the screw , but it was not symptomatic.

Discussion

Transacetabular screw is used by surgeons to improve stability in total hip arthroplasty. It has been shown to improve initial stability in cadaveric studies. However, it is known that additional screws increase neurovascular complications, although there is no consensus whether they increase osteolytic lesions. Some authors have attributed the increase in osteolytic lesions to a reaction to the debris escaping from the screw holes to the acetabular bone. In contrast, Schmalzried *et al* reported in their retrospective study that pelvic osteolysis is associated with significantly greater head size and longer follow-up than screw use. In our study, only one case of osteolysis was identified, which was in the screw group and it is not symptomatic. But our follow-up period is short. These rates may change when the follow-up period is extended. This is the limitation of our study.

Conclusion

Similar to the literature data, our study showed no difference between clinical outcome and revision rate between the groups in the short term.

Figures

Figure 1

Figure 2

	Group A (without screw)	Group B (with screw)
Patients	53	48
Age	59 (18-80)	57,8 (34-80)
Sex		
Female	30	38
Male	23	10
Diagnosis		
Osteoarthritis	34	25
Dysplasia	12	19
Others	7	4
Follow-up (months)	25,3	40,2

Figure 3

#5910

Third Body Wear of UHMPWE-on-PEEK-OPTIMA

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Introduction

PEEK-OPTIMA™ has been considered as an alternative to cobalt chrome in the femoral component of total knee replacements [1]. Whole joint wear simulation studies of both the tibiofemoral and patellofemoral joints carried out to date have shown an equivalent wear rate of UHMWPE tibial and patella components against PEEK and cobalt chrome (CoCr) femoral components [1,2]. In this study, the influence of third body wear on UHMWPE-on-PEEK was investigated, tests on UHMWPE-on-CoCr were carried out in parallel to compare PEEK to a conventional femoral component material.

Methods

Wear simulation was carried out in simple geometry using a 6-station multi-directional pin-on-plate simulator. 5 scratches were created on each PEEK and CoCr plate perpendicular to the direction of the wear test using a diamond stylus to produce scratches with a geometry similar to that observed in retrieved CoCr femoral components. To investigate the influence of scratch lip height on wear, scratches of approximately 1, 2 and 4µm lip height were created. Wear simulation of GUR 1020 UHMWPE pins (conventional, non-sterile) against the plates was carried out for 1 million cycles (MC) using 17g/l bovine serum as a lubricant using kinematic conditions to replicate the average contact pressure and cross-shear in a total knee replacement. Wear of UHMWPE pins was measured gravimetrically and the surface topography of the plates assessed using a contacting Form Talysurf. Wear factors of the pins against the scratched plates were compared to unscratched controls (0µm lip height). Minimum n=3 for each condition and statistical analysis carried out using ANOVA with significance taken at $p<0.05$.

Results

For the control tests (0µm lip height), the wear factor of UHMWPE pins was similar ($p=0.64$) against PEEK and CoCr plates, Figure 1. Against CoCr, with an increasing lip height, an exponential increase in wear factor of UHMWPE pins was observed; for PEEK, with increasing lip height, the wear factor did not show an exponential increase. When articulated against the largest scratches, 4µm, the wear factor of UHMWPE was significantly higher against CoCr than PEEK ($p=0.01$). At the conclusion of the study, on the PEEK plates, a polishing effect of the pin against the plates was observed and in the area of the wear test, the lip height of the scratches was lower than pre-test values; for the CoCr plates, no change in lip height was measured after 1MC wear simulation.

Conclusion

The exponential relationship between scratch lip height in CoCr and wear of UHMWPE has previously been described [3]. However, the trend in the wear of UHMWPE was different when articulating against scratched PEEK compared to CoCr, with a significantly higher wear factor of UHMWPE against CoCr than PEEK at a scratch lip height of 4µm. This study suggests that the third body wear behaviour of this all-polymer knee replacement will be different to that of conventional implant materials.

[1] Cowie RM, et al. 2016. JEIM 230(11):1008-1015

[2] Cowie, R. M., et al. 2018. *Orthopaedic Proceedings*. Vol. 100. No. SUPP_6. Bone & Joint Surgery.

[3] Minakawa, H. 1998. JBJS(Br); 80-B:894-9

Figures

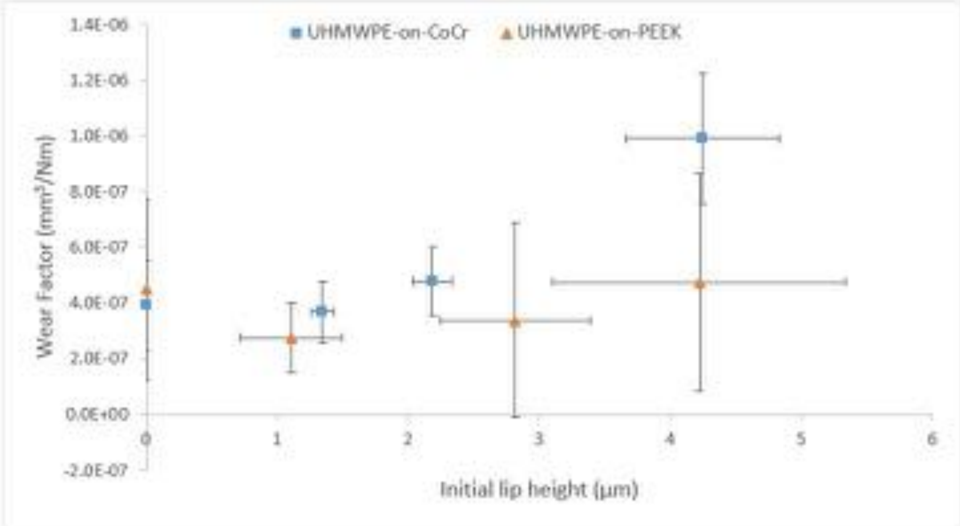

Figure 1: Mean (±95% CL) wear factor versus initial lip height (±95% CL) of UHMWPE pins against CoCr and PEEK plates scratched with a diamond stylus, minimum n=3 for each.

Figure 1

#5660

Effect of Cup Positioning on Wear of Metal-on-Polyethylene Total Hip Replacement: A Finite Element Analysis

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INTRODUCTION

Component positioning of an artificial hip joint plays a key role in durability of implant. Despite the fact that a number of numerical, experimental and clinical studies have been carried out to investigate the effects of cup inclination on polyethylene wear, steep inclination has been reported to be associated with both high [1, 2] and low [3, 4] volumetric wear. Moreover, how cup anteversion affects wear and its interaction with inclination are still unclear. To address these knowledge gaps, in this study wear and contact mechanics of a hip joint under various cup positioning has been investigated by using FEA (Finite Element Analysis).

METHOD

A Pinnacle® Marathon neutral liner 36x56mm was chosen to model the wear and creep over 3 million cycles (mc) based on the Archard's law and modified time hardening model in ANSYS, respectively. Central composite design of response surface method [5] was used to generate 9 FEA runs, where the operative inclination angles varied from 35º, 45º to 55º and operative anteversion angles differed amongst 0º, 15º and 30º. The range of cup angles were chosen to be similar to the "golden" safe zone for dislocation [6]. The gait cycle as specified in ISO 14242-1 was applied to the femoral head.

RESULT

Figure 1 shows that edge contact takes place with steep inclination and anteversion, resulting in a decreased contact area (wear contour) which intersects with cup rim, consequently increasing the contact pressure and wear penetration depth as illustrated in Figure 2. According to the FEA result summary in Figure 3, maximum wear rate, contact pressure, wear depth and Mises stress were found in the model with highest inclination and anteversion angles, i.e. Design Point (DP) 3. However, within the range of positioning angles studied, the predicted volumetric wear rates only vary from 13.68 mm^3/mc (DP6) to 13.92 mm^3/mc (DP3), which are comparable to the corresponding wear rates measured *in vitro* [7], i.e. 12.9±3.8 mm^3/mc (DP0, inclination = 35º) and 15.4±5.0 mm^3/mc (DP1, inclination = 55º).

DISCUSSION

Increased wear rate, contact pressure, wear depth and stress were predicted with a combination of steep cup inclination and anteversion, resulting from the edge contact condition. While the increase in stress and wear was modest within the range of positions tested, combinations of higher inclination and version are not uncommon and would be expected to result in more significant increases. Hence in a total hip replacement surgery it is desirable to ensure that the contact area lies well within the bearing area by avoiding excessive inclination and anteversion angles.

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6. Lewinnek et al. *The Journal of bone and joint surgery* 1978;60:217-220.

7. Ali et al. *Bone & Joint Journal Orthopaedic Proceedings Supplement* 2017;99:12.

Figures

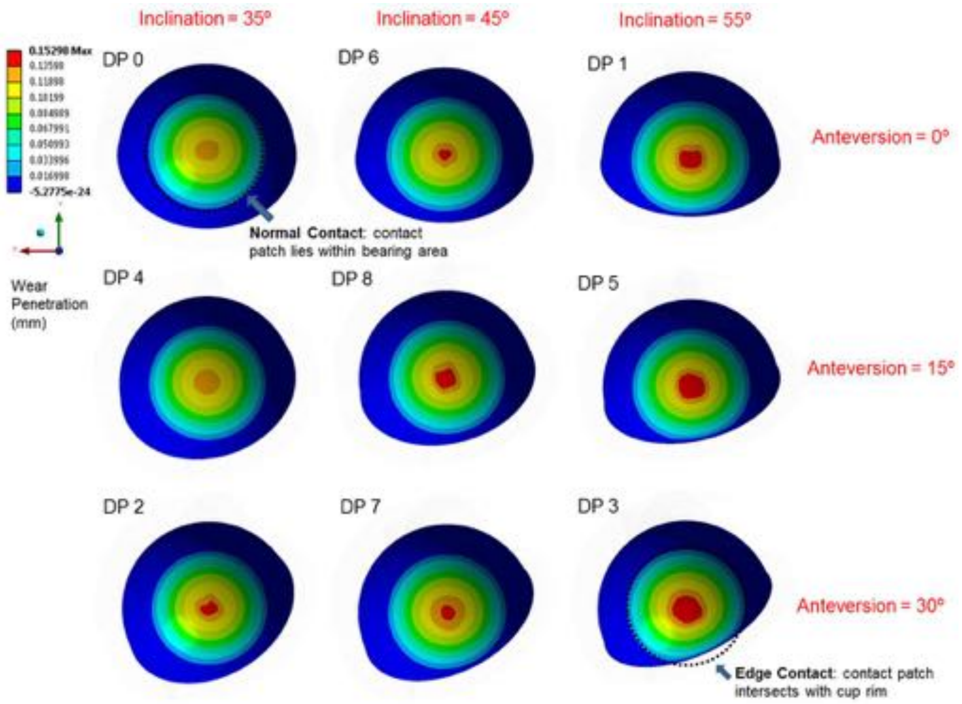

Figure 1 Wear penetration (3mc) contours of various cup positioning angles (superior view)

Figure 1

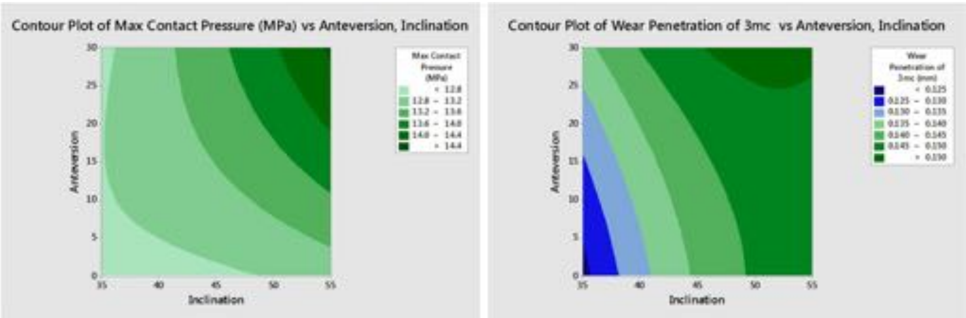

Figure 2 Contour plots of maximum contact pressure and wear penetration

Figure 2

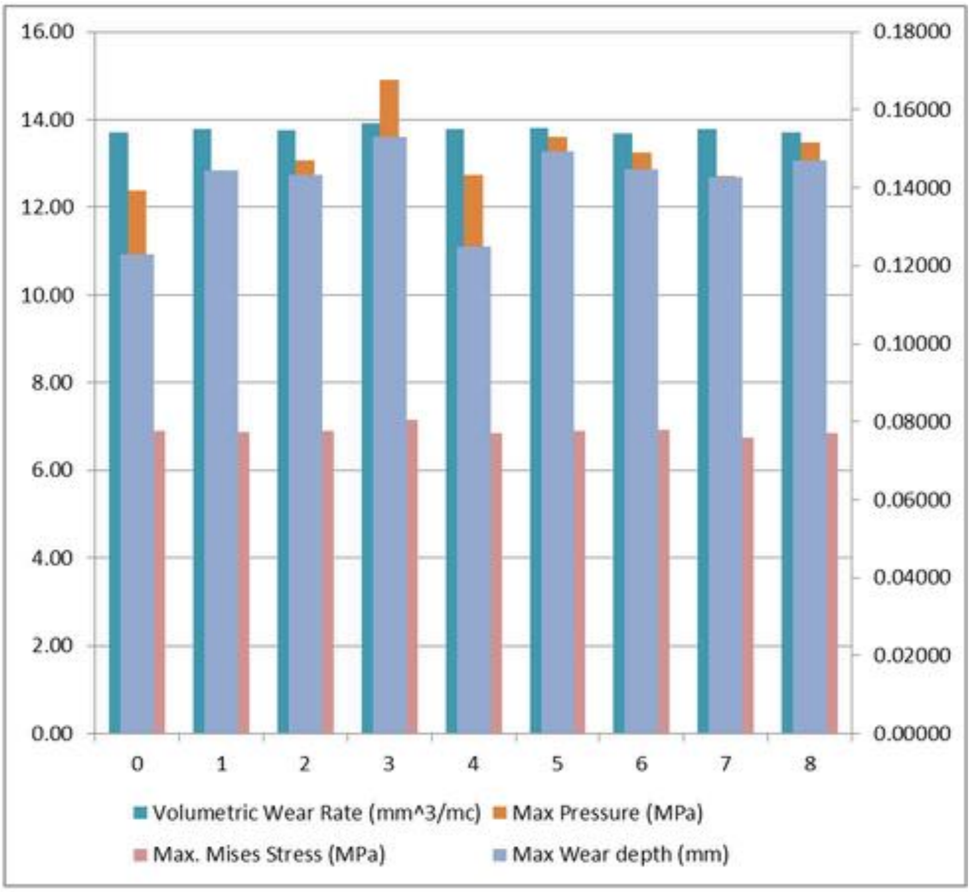

Figure 3 FEA result summary of various design points

Figure 3

#5851

Musculoskeletal Modeling Combined With a Finite Element Model to Predict Wear at the Taper Junction in Total Hip Arthroplasty

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Introduction

Fretting corrosion at the taper interface of modular connections can be studied using Finite Element (FE) analyses. However, the loading conditions in FE studies are often simplified, or based on generic activity patterns. Using musculoskeletal modeling, subject-specific muscle and joint forces can be calculated, which can then be applied to a FE model for wear predictions. The objective of the current study was to investigate the effect of incorporating more detailed activity patterns on fretting simulations of modular connections.

Methods

Using a six-camera motion capture system, synchronized force plates, and 45 optical markers placed on 6 different subjects, data was recorded for three different activities: walking at a comfortable speed, chair rise, and stair climbing. Musculoskeletal models, using the Twente Lower Extremity Model 2.0 implemented in the AnyBody modeling System™ (AnyBody Technology A/S, Aalborg, Denmark; figure1) , were used to determine the hip joint forces. Hip forces for the subject with the lowest and highest peak force, as well as averaged hip forces were then applied to an FE model of a modular taper connection (Biomet Type-1 taper with a Ti6Al4V Magnum +9 mm adaptor; Figure 2). During the FE simulations, the taper geometry was updated iteratively to account for material removal due to wear. The wear depth was calculated based on Archard's Law, using contact pressures, micromotions, and a wear factor, which was determined from accelerated fretting experiments.

Results

The forces for the comfortable walking speed had the highest peak forces for the maximum peak subject, with a maximum peak force of 3644 N, followed by walking up stairs, with a similar maximum peak force of 3626 N. The chair rise had a lower maximum peak force of 2240 N (-38.5%). The simulated volumetric wear followed the trends seen in the peaks of the predicted hip joint forces, with the largest wear volumes predicted for a comfortable walking speed, followed by the stairs up activity and the chair rise (Figure 3). The subjects with the highest peak forces produced the most volumetric wear in all cases. However, the lowest peak subject had a higher volumetric wear for the stairs up case than the average subject.

Discussion

This study explored the effect of subject-specific variations in hip joint loads on taper fretting. The results indicate that taper wear was predominantly affected by the magnitudes of the peak forces, rather than by the orientation of the force. A more comprehensive study, capturing the full spectrum of patient variability, can help identifying parameters that accelerate fretting corrosion. Such a study should also incorporate other sources of variability, including surgical factors such as implant orientation, sizing, and offset. These factors also affect hip joint forces, and can be evaluated in musculoskeletal models such as presented here.

Figures

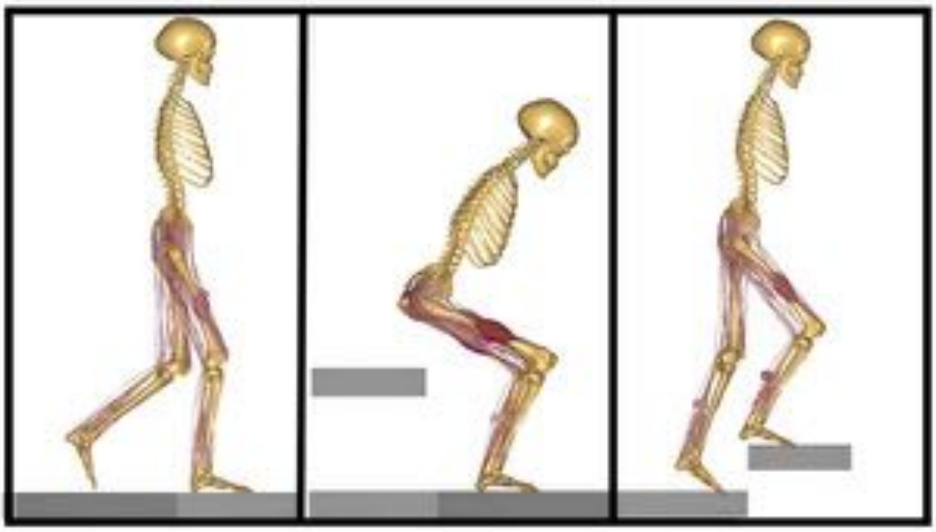

Figure 1 Different activities that were modeled using musculoskeletal modeling. Comfortable walking speed (CWS, left), chair rise, (CR, middle), and stairs up (SU, right). Grey boxes indicate the force plates used.

Figure 1

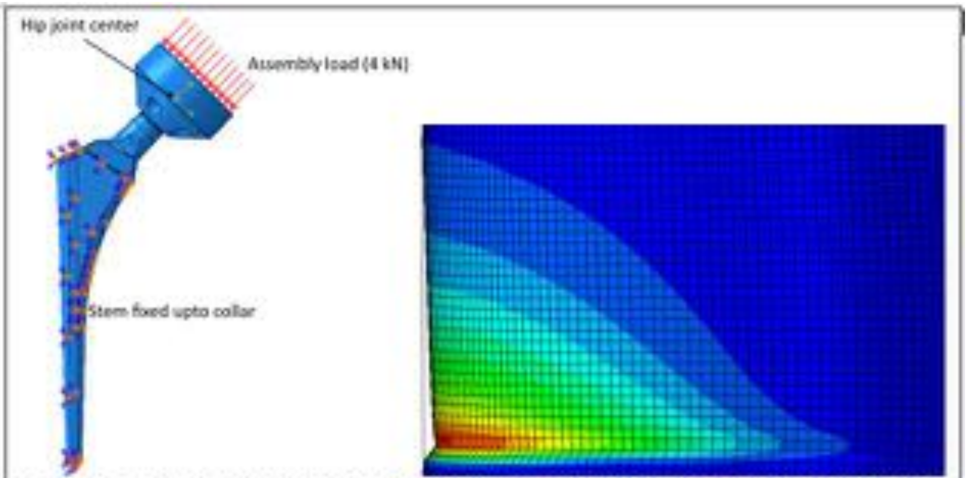

Figure 2 FEA model, Boundary conditions (left), adapted mesh (right). Nodes are moved inwards to the taper surface, changing the geometry to account for the wear.

Figure 2

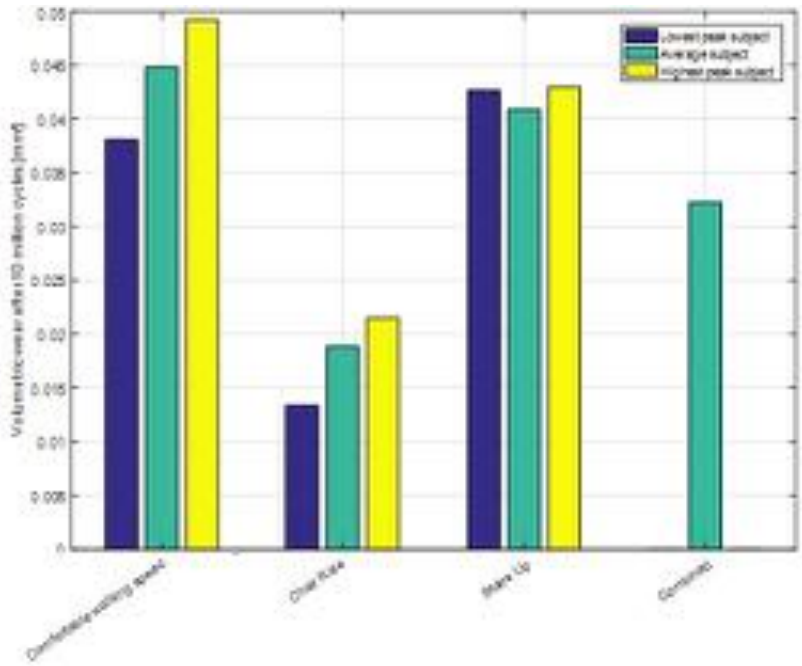

Figure 3 Volumetric wear after 10 million simulated cycles

Figure 3

#5976

Hip Wear Simulator Results of Vitamin E Blended Highly Crosslinked Polyethylene

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INTRODUCTION

Since the early 2000s, highly cross-linked (HXL) UHMWPE's have become a popular option with multiple experimental and clinical studies showing that gamma or electron radiation doses between 50-100 kGY reduce wear and potentially extend the bearing life of UHMWPE[1,2]. However, the increased wear resistance was at a compromise of mechanical properties due to the cross-linking process[2]. Vitamin E has been added to some HXL UHMWPE materials to offer a solution to the compromise by increasing oxidation resistance and maintaining sufficient fatigue strength[3]. However, limited data is available on the effect of the fabrication process, especially the method of irradiation, on the properties of the Vitamin E blended HXL UHMWPE. The purpose of this study was to evaluate the effects of adding the antioxidant vitamin E to highly crosslinked UHMWPE on wear rates.

METHODS

Wear testing was performed on six highly crosslinked UHMWPE acetabular liners containing vitamin E (0.1% wt alpha tocopherol) fabricated using the Cold Irradiation Mechanically Annealed (CIMA) process, gamma irradiated to approximately 100 kGy, and terminally gamma sterilized. The liners were paired with three 40mm CoCr femoral heads and 40mm three ceramic femoral heads. Testing was completed per ASTM F1714 and ISO 14242 on an orbital hip joint wear simulator (Shore Western, California) and lubricated with 90% bovine calf serum, 20mM EDTA, 0.2%wt. NaN_3 and DI water. A 1.1Hz Paul-type loading waveform with a peak of 2kN was used for a total of 5E6 wear cycles. Three loaded soak controls were used in parallel to adjust for fluid absorption. Samples were weighed every 5E5 wear cycles.

RESULTS

The wear rates for the HXL blended vitamin-E liners were calculated using the slope of the linear regression over the steady state and resulted in a wear rate of 0.49mg/Mc. This is a decrease of approximately 95% compared to the 9.54 mg/Mc 28mm ID conventional UHMWPE wear rates as well as a notable difference for the other HXL UHMWPE liner wear rates discussed in the review[3] (Figure 1).

DISCUSSION

HXL blended vitamin-E 40mm liners demonstrated an approximate 95% reduction in wear rates compared to a 28mm ID conventional UHMWPE[3]. The reduced wear rate confirmed the design expectation that a higher irradiation dose in the fabrication process resulted in an increased amount of polymer crosslinking. Additionally, the wear rate of the HXL blended vitamin-E liners studied was well below 20mg/Mc, which was shown by Dowd et al. to be the threshold of osteolysis in THA.

SIGNIFICANCE

The HXL vitamin E blended UHMWPE liner tested in this study demonstrated reduced wear rates by approximately 95% compared to conventional polyethylene. Osteolysis-causing wear debris is reduced while maintaining other mechanical properties. This liner material and manufacturing process is a promising alternative to conventional polyethylene but long term clinical results are warranted.

References

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Figures

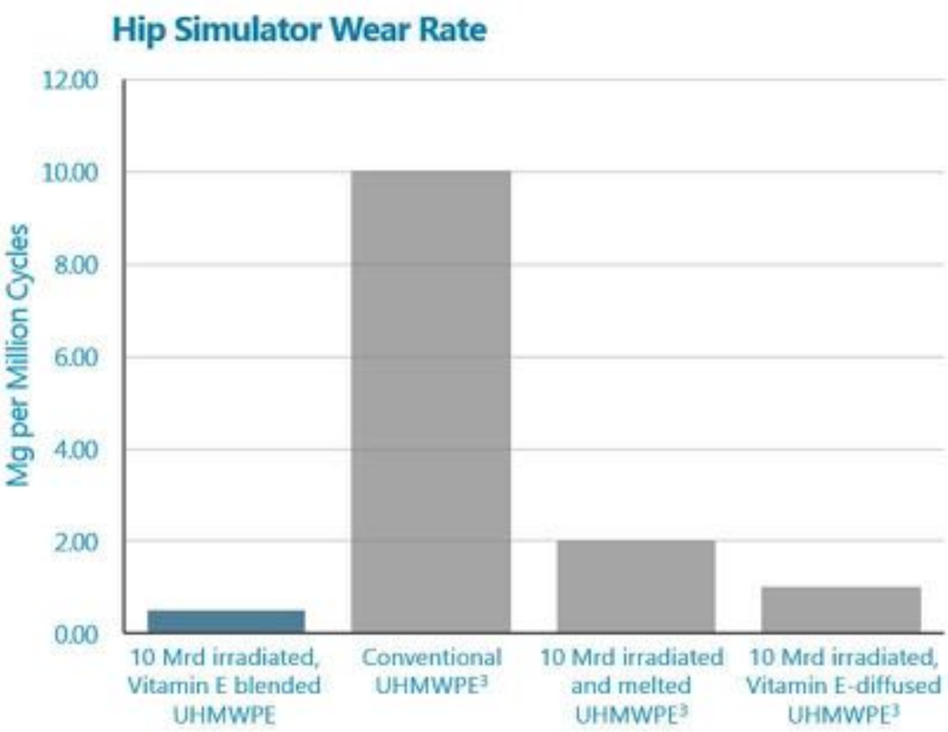

Figure 1

Review: Does Total Hip Arthroplasty Wear Simulation Represent Heavy and Active Patients?

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Introduction

Hip arthroplasty is considered common to patients aged 65 and over however, both Jennings, et al., (2012) and Bergmann (2016) found THA patients are substantially younger with more patients expecting to return to preoperative activity levels. With heavier, younger, and often more active patients, devices must be able to support a more demanding loading-regime to meet patient expectations. McClung (2000) demonstrated that obese patients can display lower wear-rates with UHMWPE bearing resulting from post-operative, self-induced reduced ambulatory movement, thus questioning if obese kinematics and loading are indeed the worst-case.

Current loading patterns used to test hip implants are governed by ISO 14242-1 (2014). This study aimed to characterize a heavy and active population (referred to as HA) and investigate how the gait profile may differ to the current ISO profile.

Method

A comprehensive anthropometric data set of 4082 men (Gordon, CC., et.al., 2014) was used to characterize a HA population. Obese and HA participants were classed as BMI ≥30 however HA participants were identified by applying anthropometric ratios indicative of lower body fat, namely ''waist to height'' (i.e. WHtR <0.6) and ''waist to hip'' (i.e. WHpR <0.9).

Findings

Of 491 obese participants 61 were identified as HA (i.e. BMI> 30, WHpR<0.9; WHtR<0.6) (Figure 1). These characteristics were validated against a population of elite rugby players that were found to be a true reflection of HA patients (Figure 2). Combining the Army and Rugby populations resulted in a weight of 123kg for the 95th percentile, which based on 3x body weight (as referenced in ISO14242-1) would equate to a peak simulator load of 3620N.

Conclusion

Characterization of a HA population was successfully defined as clinically obese by BMI, but with WHtR and WHpR associated with lower body fat. The author was unable to identify gait characteristics of a HA population through existing literature.

Future Work

A gait-lab based study will be used to compare literature-based kinematics of obese subjects to those of HA subjects. A worst-case gait cycle can then be established for standard walking and other activities and translated into hip simulator parameters for HA patients.

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Figures

Figure 1 - Height Vs Weight Distribution of HA and Obese

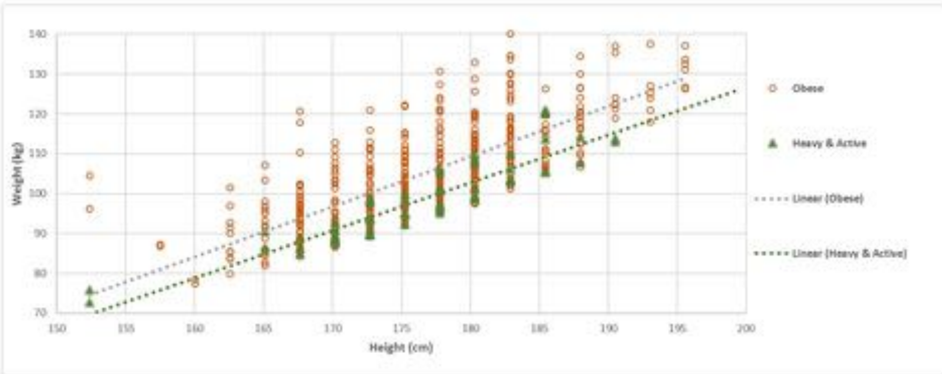

Figure 1

Figure 2 - Height Vs Weight Distribution of HA and Elite Rugby Players

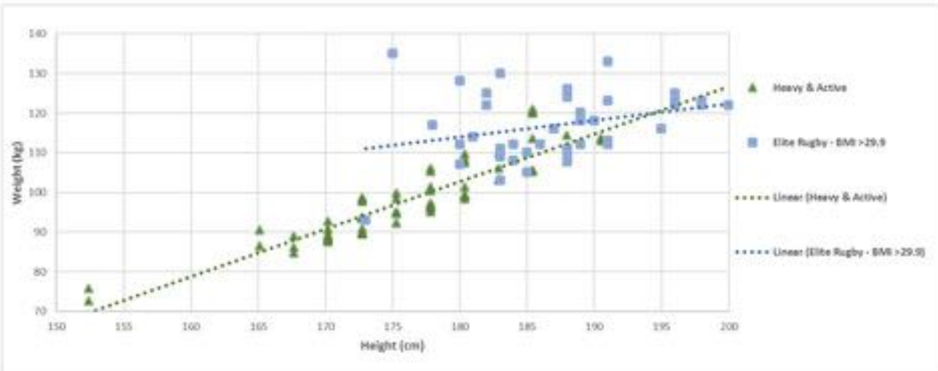

Figure 2

#5691

Mixed Lubrication Wear Model of the Human Knee Implant

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The number of knee replacement surgeries have increased rapidly over the past few years. However, these implants can have limited life due to the issue of wear. An accurate lubrication model is an important component in understanding and designing joints to deliver lower joint wear and the risks associated with such wear.

One of the main challenges in tribological modelling of the knee implant is capturing the effects of the complex geometry on the joint performance. Most current models assume a single point of contact, with zero pressure and deformation assumed elsewhere. Unlike the hip implant, which can be described as a circular or elliptical contact, the knee implant involves a geometry that cannot be easily approximated into a regular shape. For this reason, the elastohydrodynamic lubrication equations become computationally expensive and challenging to solve. Finite element methods are required to capture the complex geometry and calculate deformations and how they vary spatially over the joint surface. Furthermore, the irregularity and asymmetry of the geometry provides no guarantee that well-defined contact points exist.

A mixed lubrication model for a human knee implant is presented, incorporating the irregularity of the knee geometry. Tribological conditions in the mixed lubrication regime are calculated using a statistically representative description of surface roughness. This approach involves the flow factors approach of Patir and Cheng [1], and Greenwood and Tripp [2] approach for asperity contact. From this, the evolution of both the gross geometry and the change in surface roughness due to wear is determined.

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#5931

Development of a Multi-Station Shoulder Simulator for Wear Performance Analysis of Shoulder Implants

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Background

Medical advances and an ageing population mean that more people than ever rely on artificial joints. In the past years, shoulder joint replacement has developed rapidly and the numbers of shoulder prostheses implanted increased dramatically. Wear is one of the main contributors to the failure of shoulder implants. It is therefore important to measure the wear properties of the articulating surfaces within the joint *in vitro*. Investigation of wear characteristics through a comprehensive range of motion using a sophisticated shoulder simulator would reveal the durability of the material, the performance of component design and the safety analyses of prostheses. The purpose of the work was to develop and validate a multi-station shoulder simulator, which could accurately simulate physiological gleno-humeral forces and displacements during activities of daily living.

Materials and Methods

Imperial shoulder simulator was designed with six articulating stations and one loaded soak control station for anatomical shoulder system wear simulation. It gives an adduction-abduction (AA) range of-15° to 55°, flexion-extension (FE) range of -90° to 90° and internal external rotation (IER) range of 15° to -90°. The rotations are applied simultaneously to the humeral implants by using stepper motors with integral position encoders. Axial and shear loadings to each glenoid implant were applied using pneumatic cylinders. Force controlled translations were recorded using load cells and LVDTs, and a data acquisition system. Pneumatic cylinders were also installed to work to counterbalance weights during the motion of adduction-abduction. All bearing pairs are within isolated and sealed test chambers to prevent loss of fluid through evaporation, and cross contamination of third body wear (as recommended in F1714-96). The simulator is controlled by LabVIEW program allowing to reproduce shoulder activities of daily living.

Results

A commissioning trial was conducted when shoulder implants were subject to rotational and translational motions and loading to replicate the ‘combing’ activity of daily living. The motion ranges were typically 5° to 15° in AA, 15° to 80° in FE, and -30° to -20° in IER with applied loads from 60 to 440 N, principally along the medio-lateral direction. The waveform was at frequency of 1 Hz. The activity was loaded at 250,000 cycles around 3 full days, when test and control specimens should be cleaned, measured and then re-installed into the simulator. The results from kinematic and kinetic inputs and outputs were obtained from the trial study.

Discussion

A multi-station shoulder simulator was successfully developed, which is capable of reproducing typical activities of daily living by applying physiological patterns of motion and load. The performance of the simulator was validated in the commissioning trial, which leads to evaluation of novel implant designs.

#6196

Electrochemical Impedance Spectroscopy as a Method to Distinguish Corrosion Severity and Damage Modes in Retrieved Femoral Heads

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Electrochemical Impedance Spectroscopy as a Method to Distinguish Corrosion Severity and Damage Modes in Retrieved Femoral Heads

Introduction

Corrosion at modular junctions of total hip replacements has been identified as a potential threat to implant longevity, resulting in efforts to determine appropriate countermeasures. Visual scoring and volumetric material loss measurements have been useful tools to elucidate various clinical and design factors associated with corrosion damage. However, corrosion involves electron exchange that results in chemical changes to biomedical alloys, and electrochemical assessment may therefore be a more appropriate approach to understand the phenomenon. The purpose of this pilot study was to electrochemically distinguish the severity of corrosion in retrieved femoral heads. A secondary goal was to identify the potential of electrochemical impedance spectroscopy (EIS) as a method to identify different forms of corrosion damage.

Methods

Twenty femoral heads were identified from a larger study of total hip replacements, obtained as part of an ongoing multi-center IRB-approved retrieval program. Using a previously established 4-point scoring method, components were binned by taper damage: 10 components were identified as having severe damage, 7 with moderate damage and 2 with mild damage. One (1) unimplanted control was included to represent minimal corrosion damage. All components were then characterized using electrochemical impedance spectroscopy under the frequency domain: a 10 mV sinusoidal voltage, ranging from 20 kHz to 2 mHz, was applied to the taper of a femoral head (working electrode) filled with a 1M solution of PBS with a platinum counter electrode and chlorided silver reference electrode. Absolute impedance at 2 mHz ($|Z_{0.002}|$), and max phase angle (θ) were assessed relative to taper damage severity. After least-squares fitting of the EIS data to a Randles circuit with a constant phase element, circuit elements: polarization resistance (Rp), CPE-capacitance, and CPE-exponent were also evaluated. Seven (7) of the 10 severely corroded components were further examined with scanning electron microscopy to identify corrosion modes. For all statistical analyses, significance was determined at alpha=0.05.

Results

Taper damage was strongly correlated with both $|Z_{0.002}|$ (ρ = -0.857, p<0.001; Figure 1a) and CPE-capacitance (ρ=0.913, p<0.001; Figure 1b). Taper damage was moderately associated with max phase angle (ρ= -0.483, p=0.031), CPE-exponent (ρ= -0.653, p=0.002) and Rp (ρ=0.556, p=0.011). Log-log plots of the strongest predictors of taper damage ($|Z_{0.002}|$and CPE-capacitance) identified some clustering among severely corroded components (Figure 2). SEM analysis revealed that components with log|Z| < 5.5 and log CPE-T ≥ -4.2 all exhibited evidence of severe intergranular corrosion attack

(Figure 3).

Discussion

The results of this pilot study highlight that electrochemical impedance spectroscopy is useful in determining corrosion severity in retrieved femoral heads, and may also identify intergranular corrosion attack. For an undamaged taper, the self-passivating behavior of CoCrMo creates a surface that opposes charge transfer, but greater corrosion appears to compromise this barrier. The observed trend of low impedance but high capacitance for severely corroded components with intergranular corrosion may signal charge storage at the boundaries of individual grains. Additional work is underway to characterize this behavior.

Figures

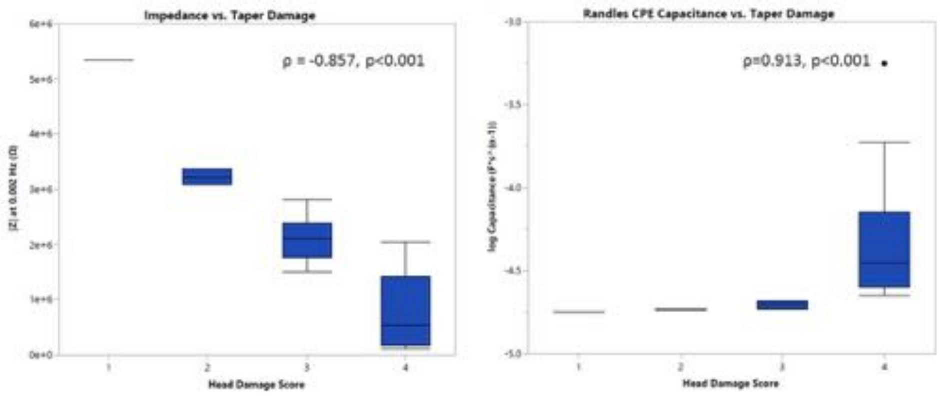

Figure 1

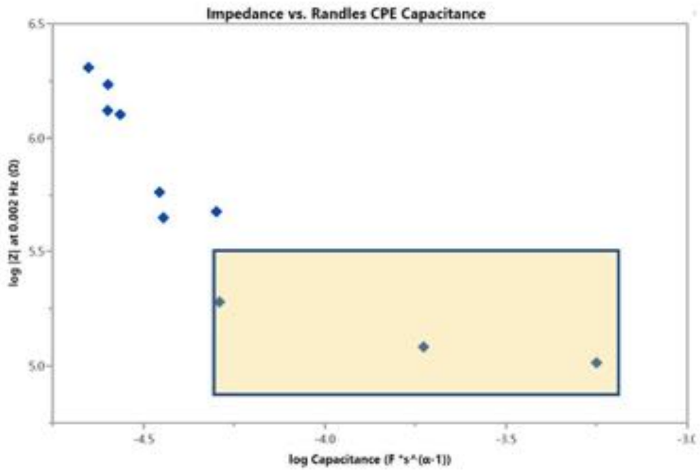

Figure 2

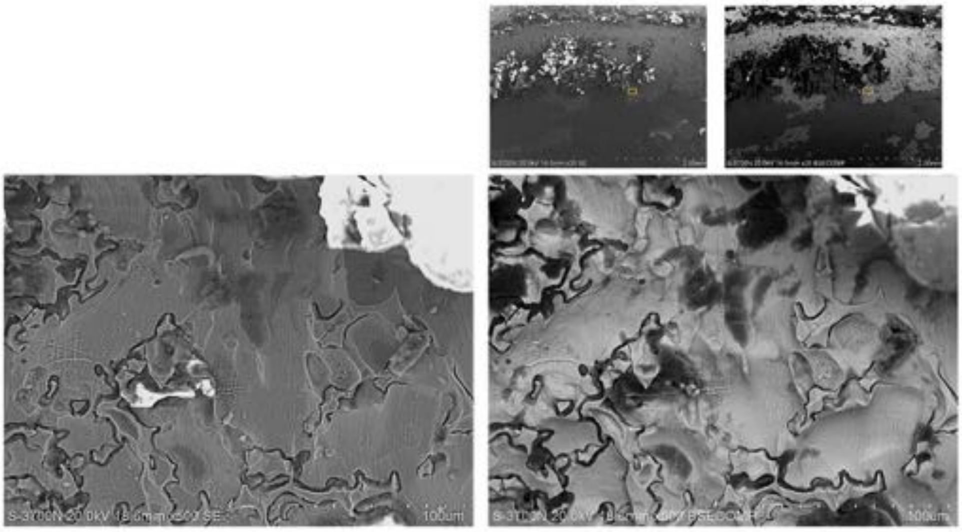

Figure 3

#5677

Gross Taper Failure of TMFZ Stems in Total Hip Arthroplasty

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INTRODUCTION:

Gross taper failure (GTF) in Total Hip Arthroplasty has increasingly been reported for one particular combination consisting of a small taper Ti-12Mo-6Zr-2Fe-alloy (TMFZ) stem fitted with a cobalt-chromium alloy (CoCr) head articulating with polyethelyne (PE)[1,2]. The aim of this study was to quantify the stem material loss and to investigate the influence of design parameters and time in situ from revised stem components.

MATERIALS & METHODS:

10 TMZF titanium-alloy stems (Accolade I, Stryker, 127°, size range: 1.5 to 5.5) that had been fitted with 36mm V40 CoCr-alloy heads (LFIT, Stryker: head length range: +5 to -5mm) were available for material loss analysis. All stems failed catastrophically by disassociation (n=9) or disassociation and fracture (n=1) [Fig. 1]. Surfaces of the retrieved stems were reconstructed using a structured-light 3D scanner (Artec Spider, Artec3D, Luxembourg; 100µm resolution; 50µm point accuracy). Material loss was calculated as the difference between the volume of the reconstructed stems and that of a pristine stem of the same size [Fig. 2].

RESULTS:

Stem wear was large with large variations (mean: 713.6mm^3; SD: 252.3mm^3). There was no significant influence of the time in situ (p=0.36), stem neck length (p=0.178), stem offset (p=0.378) or head length (p=0.35) on the amount of material lost. Three types of stem damage directly associated with specific head length were observed: ‘Bird Beak’ (tilting into varus) for long heads (+5mm; n=8), ‘Toothpick’ (no tilting) for the neutral head (0mm; n=1) and ‘Trumpet’ (tilting into valgus) for the short head (-5mm; n=1) [Fig. 3].

CONCLUSIONS:

GTF of TMZF stems is associated with large amounts of stem material loss. The amount does not correlate with time in situ nor any head or stem design parameter. GTF starts when corrosion has widened the female head taper sufficiently in order for bottoming out to occur. This process also depends on patient and surgeon factors, which were not available for analysis and which could help to explain the missing association. Once bottoming out has occurred, the head is not prevented anymore to rotate on the stem taper, causing abrasive stem taper wear with a head length specific pattern [Fig. 3]. Since GTF failures are not associated with particular design parameters all patients fitted with this particular stem/head combination should be closely monitored.

Figure 1: The analysed GTF Stems (n=10).

Figure 2: Left: 'Toothpick' wear pattern. Middle: 3D reconstruction. Right: Difference between pristine and damaged geometry (i.e. material loss) shown in red.

Figure 3: Head length influence on GTF wear pattern. Long head (5+mm): 'Bird Beak'; neutral head (0mm): 'Toothpick'; short head (-5mm): 'Trumpet'.

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2. Raju S, Chinnakkannu K, Puttaswamy MK, Phillips MJ: Trunnion Corrosion in Metal-on-Polyethylene Total Hip Arthroplasty: A Case Series. J Am Acad Orthop Surg 25(2):133, 2017

Figures

Figure 1

Figure 2

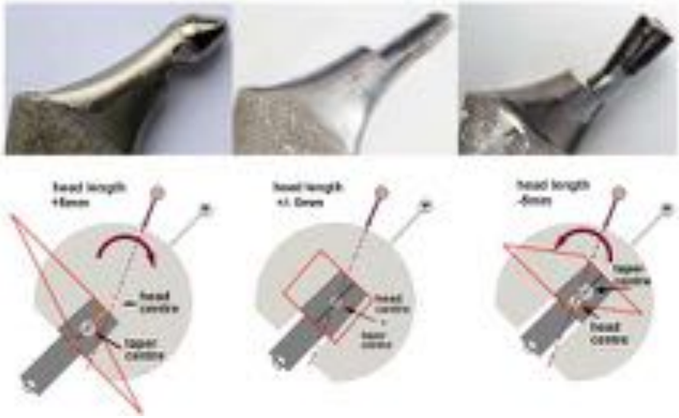
head length
head centre
taper centre
head length
head centre
head length
taper centre
head centre

Figure 3

#5891

Is There a Difference in the Wear Performance of MOM Pinnacle Implants Manufactured Before and After 2006?

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Background:Previous studies have suggested that metal-on-metal Pinnacle (DePuy Orthopaedics, Warsaw, USA) Hip Replacements (Figure 1), implanted after 2006, exhibit higher failure rates. This was attributed to the production of implants with reduced diametrical clearances between their bearing surfaces, speculated to be outside manufacturing tolerances. This study aimed to better understand the performance of Pinnacle Systems manufactured before and after this event.

Methods:Ninety-Two retrieved MOM Pinnacle hips were analysed (Figure 1); 45 were implanted before 2007 and 47 from 2007 onwards. Patient, implant and surgical characteristics of the two groups were compared to identify any potential confounding factors. All head components were 36mm in diameter, composed of cobalt-chromium and paired with 12/14 Corail (n=52) or Summit (n=40) titanium femoral stems, which are comparable in design. The volume of material lost from their bearing and taper surfaces was measured using coordinate and roundness measuring machines. These outcomes were then compared statistically using linear regression models, adjusting for potentially confounding factors.

Results:The median bearing wear rate of the ‘pre-2007’ and ‘2007 onwards’ groups were 2.3mm^3/years (1.6-9.7) and 3.8mm^3/years (2.8-8.1), respectively (Figure 2), (P= 0.67). The median taper wear rate of the pre-2007 implants was 0.81mm^2/year, while the ‘2007 onwards’ group had a median wear rate of 0.19mm^2/year, (P= 0.39). Pinnacles implanted from 2007 onwards were revised after a mean time of 50 months, which was significantly earlier than the ‘pre-2007’ hips (96 months), (P = <0.001). However, there was also a clear trend of a reduction in the time to revision year-on-year from 2003, Figure 3.

Conclusion: There was no significant difference between the bearing and taper wear rate of Pinnacle Systems implanted before 2007 and from 2007 onwards; this suggests that the performance of these implants was not affected by the speculated change in diametrical clearance, thought to have occurred in 2006. Despite their comparable wear rates, the ‘pre-2007’ hips remained implanted for nearly twice the number of months as the ‘2007 onwards’ group. This finding was attributed to the increased surveillance of MOM hips, following MRHA advice and several high-profile failures. This decreasing trend in time to revision was also identified in Pinnacle hips implanted prior to 2007 (Figure 3).

Figures

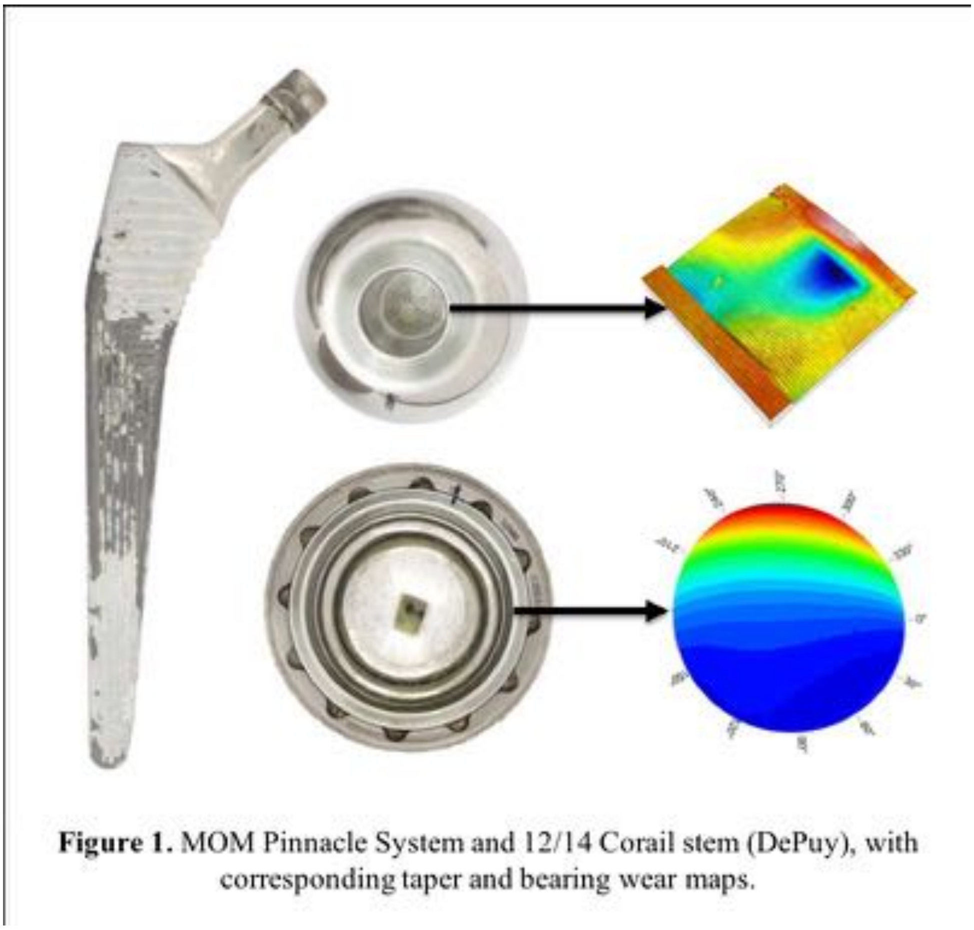

Figure 1

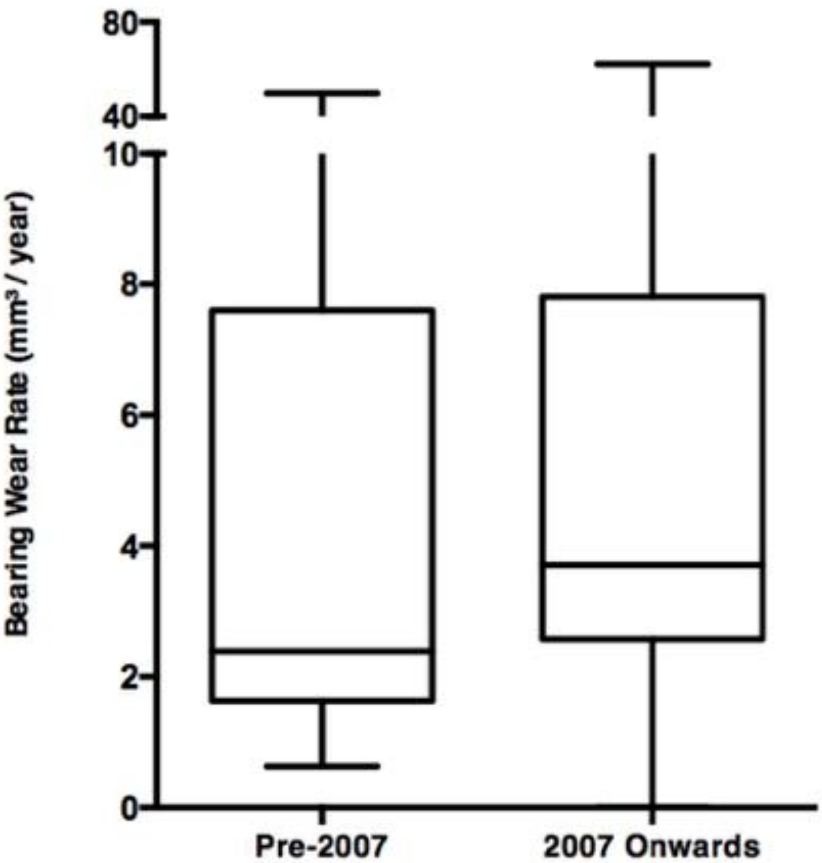

Figure 2. Bearing wear rate of Pinnacle Systems implanted before 2007 and from 2007 onwards.

Figure 2

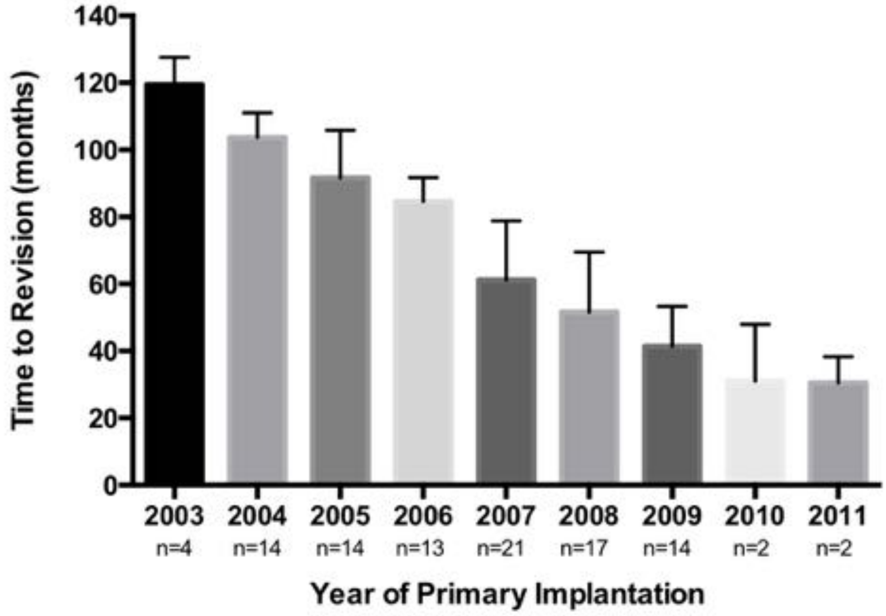

Figure 3. Bar chart plotting the year of primary implantation against the time to revision of the Pinnacle hips.

Figure 3

#5633

Taper-Trunnion Junction and Bearing Surface Wear Measurement of Metal-on-Cross-Linked Polyethylene Total Hip Replacements in a Hip Joint Simulator

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Introduction

Metal-on-polyethylene (MoP) is the most commonly used bearing couple in total hip replacements (THRs). Retrieval studies report adverse reactions to metal debris (ARMD) due to debris produced from the taper-trunnion junction of the modular MoP THRs[1, 2]. Matharu *et al*[3] showed that the risk of ARMD revision surgery is increasing in MoP THRs. To the authors' best knowledge, no hip simulator tests have investigated material loss from the taper-trunnion junction of contemporary MoP THRs.

Methods

A 6-station anatomical hip joint simulator was used to investigate material loss at the articulating and taper-trunnion surfaces of 32mm diameter metal-on-cross-linked polyethylene (MoXLPE) joints for 5 million cycles (Mc) with a sixth joint serving as a dynamically loaded soak control. Commercially available cobalt-chromium-molybdenum (CoCrMo) femoral heads articulating against XLPE acetabular liners (7.5Mrad) were used with a diluted new-born-calf-serum lubricant. Each CoCrMo femoral head was mounted on a 12/14 titanium alloy trunnion. The test was stopped every 0.5Mc, components were cleaned and gravimetric measurements performed following ISO 14242-2[4] and the lubricant was changed. Weight loss (mg) obtained from gravimetric measurements was converted into volume loss (mm^3) and wear rates were calculated from the slopes of the linear regression lines in the volumetric loss versus number of cycles plot for heads, liners and trunnions. Additionally, volumetric measurements of the head tapers were obtained using a coordinate measuring machine (CMM) post-test. The surface roughness (Sa) of all heads and liners was measured pre and post-test. At the end of the test, the femoral heads were cut and the roughness of the worn and unworn area, Figure 1, was measured. Statistical analysis was performed using a paired-t-test (for roughness measurements) and an independent sample t-test (for wear rates).

Results and Discussion

The mean volumetric wear rates for CoCrMo heads, XLPE liners and titanium trunnions are shown in Figure 2. There was a statistically significant decrease ($p<0.001$) in the Sa of the liners post-test. This is in contrast to the femoral heads roughness in which no change was observed ($p = 0.338$). This head roughness result matches with a previous MoP *in vitro* test [5]. The Sa of the head tapers on the worn area showed a statistically significant increase ($p<0.001$) compared with unworn, with an associated removal of the original machining marks. The mean volumetric wear rate of the head tapers obtained using the CMM (0.028 ± 0.016 mm^3/Mc) was not statistically different ($p=0.435$) to the mean volumetric wear rate obtained gravimetrically (0.019 ± 0.020 mm^3/Mc) for the femoral heads. Therefore, wear of the heads arose mainly from the internal taper. The mean wear rates of the CoCrMo taper and titanium trunnion are in agreement with a MoP explant study[6].

Conclusion

This is the first long-term hip simulator study to report wear generated from the taper-trunnion junction of MoP hips.

References

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Figures

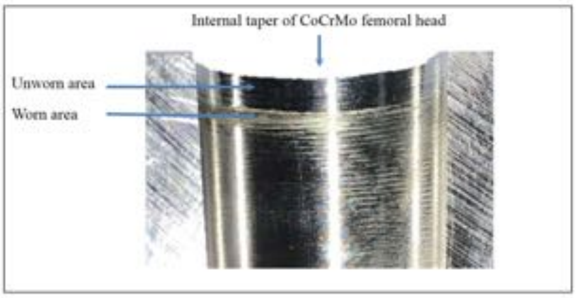

Figure 1 The internal taper of test CoCrMo femoral head showing unworn and worn areas.

Figure 1

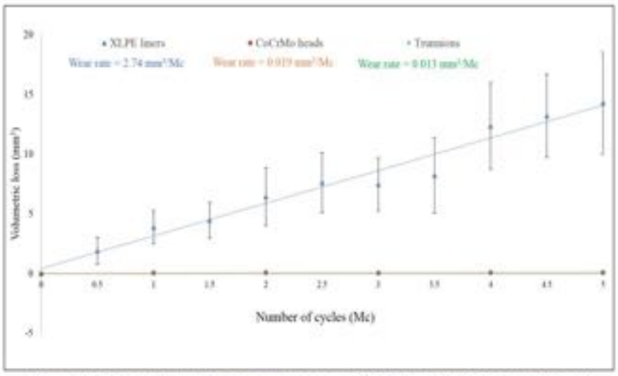

Figure 2 Mean volumetric measurements of XLPE liners, CoCrMo heads and titanium trunnions. (Error bars represent standard deviation)

Figure 2

#6007

Biological, Chemical and Mechanical Damage Modes in Corrosion of CoCrMo Acetabular Liners

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INTRODUCTION: Retrieval analyses of head-neck and neck-stem modular connections have indicated the dominant damage mode to be mechanically-assisted crevice corrosion (MACC) and wear. It is unclear whether the same applies to acetabular shell-liner tapers, since they differ from other taper junctions in geometry, taper stiffness, taper angle, proximity to tissue and resulting mechanical behavior. The goal of this study is to assess the corrosion and MACC modes in retrieved acetabular tapers and to document the nature of the damage present. We hypothesize that the nature of the corrosion and tribocorrosion damage is more likely due to crevice corrosion or other corrosion processes, rather than MACC.

MATERIALS AND METHODS: Twenty-two retrieved CoCrMo acetabular liners were obtained from the Implant Retrieval Center at Drexel University. Implant surfaces were analyzed for signs of corrosion and wear-related damage using Digital Optical Microscopy (DOM), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). SEM analysis is able to distinguish between metal/alloy (lighter regions in backscatter mode), oxides (intermediate contrast regions in backscatter mode) and carbon-rich (e.g., biological) materials (dark regions in backscatter mode). EDS further confirms the presence of metal/alloy or metal oxides or carbon-rich deposits by identifying specific elements present.

RESULTS AND DISCUSSION: All observed samples showed visible signs of damage. Figure 1 shows an example of severe corrosion damage. The inset is a DOM image of the damaged area, and the SEM micrograph (backscatter mode) shows severe intergranular corrosion and presence of biological matter (confirmed with EDS) in the same area. Figure 2, from the same sample, is in secondary electron mode, adjacent to the heavily damaged zone. This region shows evidence of original machining marks (Fig. 2), but no fretting damage. Instead, direct corrosion attack leading to pitting and intergranular corrosion is seen, implying fretting did not contribute to the severe damage. Additionally, non-contact regions of the taper exhibited pitting, intergranular corrosion and documented evidence of cell-like remnants (Figure 3). Thus, in these regions, MACC processes were not apparent and other factors (e.g., solution, biological) appear to have dominated the corrosion damage seen.

Also, the wrought high carbon CoCrMo (ASTM F-1537) microstructure is comprised of submicron-scale molybdenum silicate (Mo-Si) particles and a high number/volume of micro-scale metal carbides (approximately 10^8particles/mm^3). These particles when released from the alloy become ubiquitous within the corroded region and were found engulfed within the cell-like structures (Figure 3). Thus, particles released can lead to increased phagocytic activity at the implant surface.

CONCLUSION: Corrosion damage in acetabular tapers is significantly different than that seen in typical head-neck tapers, with biologically/chemically driven corrosion being more dominant than MACC. In some implants, there are signs of fretting-related damage and material transfer, however these are not always accompanied by severe corrosion. In some regions little to no fretting damage is observed and instead a direct pitting, etching or intergranular form of attack is observed. Significant corrosion damage OUTSIDE of the taper region has also been observed in these retrievals in regions where it is impossible to have fretting crevice corrosion.

Figures

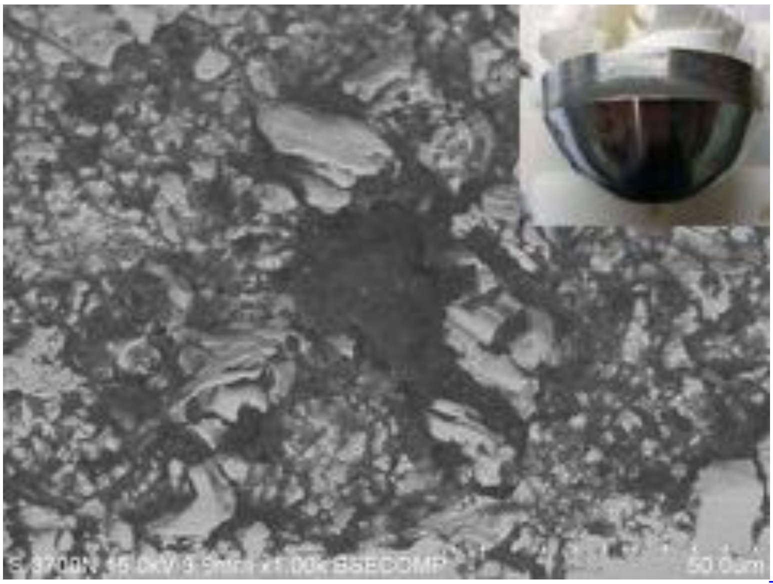

Figure 1

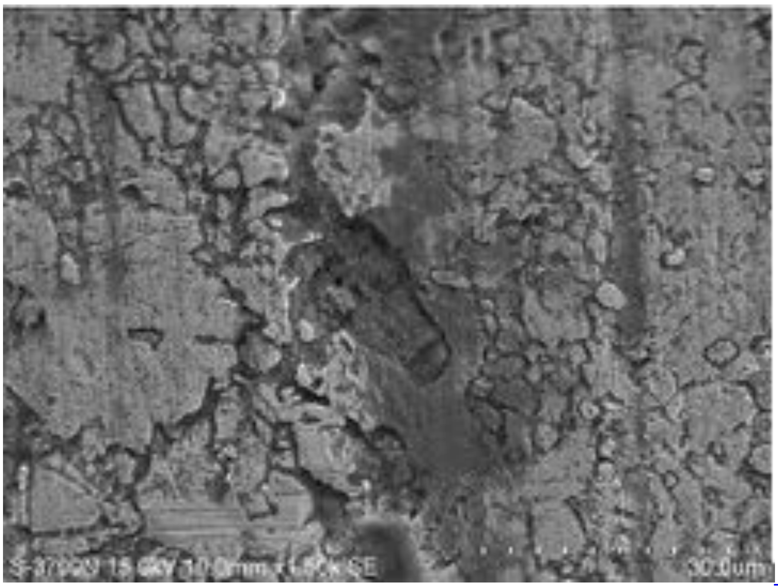

Figure 2

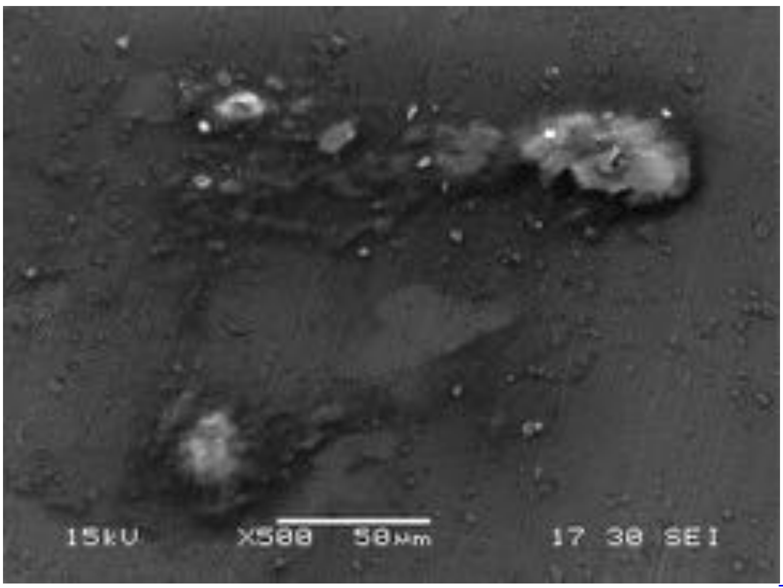

Figure 3

#6160

Fretting Corrosion Characteristics of Ti6Al4V vs. TMZF Titanium Alloys in Simulated Body Fluid

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Introduction: Titanium and its alloys are attractive biomaterials because of their desirable corrosion, mechanical, biocompatibility and osseointegration properties. Specifically, β – titanium alloys like the TMZF possess other advantages. For example, its lower modulus relative to the Ti6Al4V alloy reduces stress shielding effect in Total Hip Arthroplasty (THA) and the replacement of V in the Ti6Al4V alloy, eliminates V-induced toxicity *in-vivo*. Unfortunately, implants made of TMZF were later recalled after about a decade in the orthopaedic market due to higher than acceptable revision rates. The purpose of this study was to compare the fretting corrosion characteristics of Ti6Al4V and TMZF titanium alloys; its findings hopes to inform better design of β – titanium alloys for future applications in THA.

Method: A ball-on-flat configuration was utilised in this study to achieve a Hertzian point contact for CoCrMo – Ti6Al4V and CoCrMo – TMZF material combinations. These were assessed at a fretting displacement of ±50 µm at an initial contact pressure of 1 GPa. Each fretting test lasted 6000 cycles at a frequency of 1 Hz. A two-electrode cell set-up was used to monitor *in-situ* open circuit potential (OCP). The simulated physiological solution consisted of Foetal Bovine Serum (FBS) diluted to 25% with Phosphate Buffered Saline (PBS) and 0.03% Sodium Azide (SA) balance. The temperature was kept at ~37°C. Corrosion products on the worn surfaces and subsurface transformations in both alloys were characterised using the Scanning and Transmission Electron Microscopy (SEM/TEM) to obtain high resolution micrographs. The samples were prepared using a FIB-SEM. Bright-field, dark-field and selected area electron diffraction (SAED) patterns were all captured using a scanning TEM (STEM) and Energy Dispersed X-Ray spectroscopy (EDX) mapping was carried out.

Results: The results showed that fretting regime transition from partial-slip to gross slip was delayed a few hundred cycles for TMZF relative to the Ti6Al4V (see Figure 1). This indicates that the lower modulus of TMZF is reflected in the degree of elastic deformation it accommodates before transition to plastic shear at the fretting interface. The OCP directly corresponded to the fretting regime for both material combinations (see Figure 2). Surface and subsurface characterisation of both alloys show differences in the structure of their mechanically mixed corrosion products and metallurgical transformations. Interestingly, an amorphous Co-rich layer was seen across the TMZF surface (see Figure 3) whereas, pitting corrosion products from the CoCrMo alloy was seen on the Ti6Al4V alloy (see reference [1]).

Conclusion: In summary, the difference in the fretting behaviour of Ti6Al4V and TMZF corresponds to the combined differences in their modulus and surface chemistry. This directly corresponds to the differences observed in the OCP behaviour. However, the main differences are observed in the nature of their corrosion products and subsurface metallurgical transformations which might shed some light on the higher failure rates of the TMZF alloy.

References

[1] A. O. Oladokun, "Mechanism of fretting corrosion at the modular taper interface of hip prosthesis," PhD, University of Leeds, 2017.

Figures

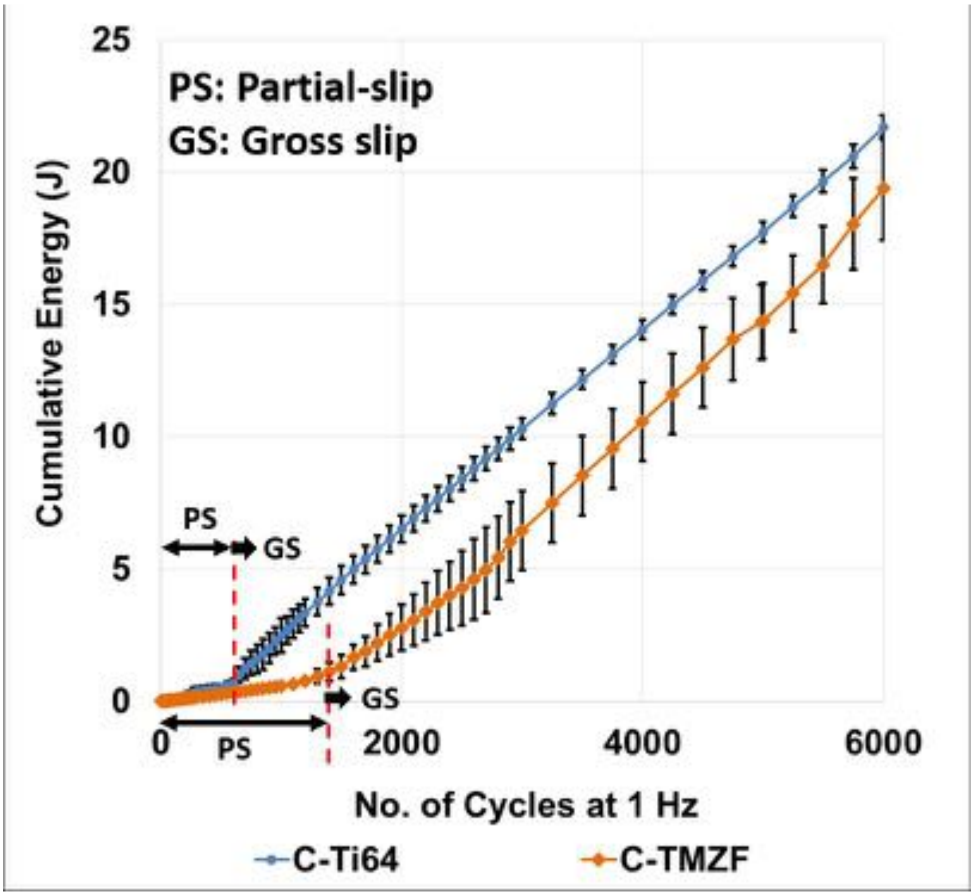

Figure 1

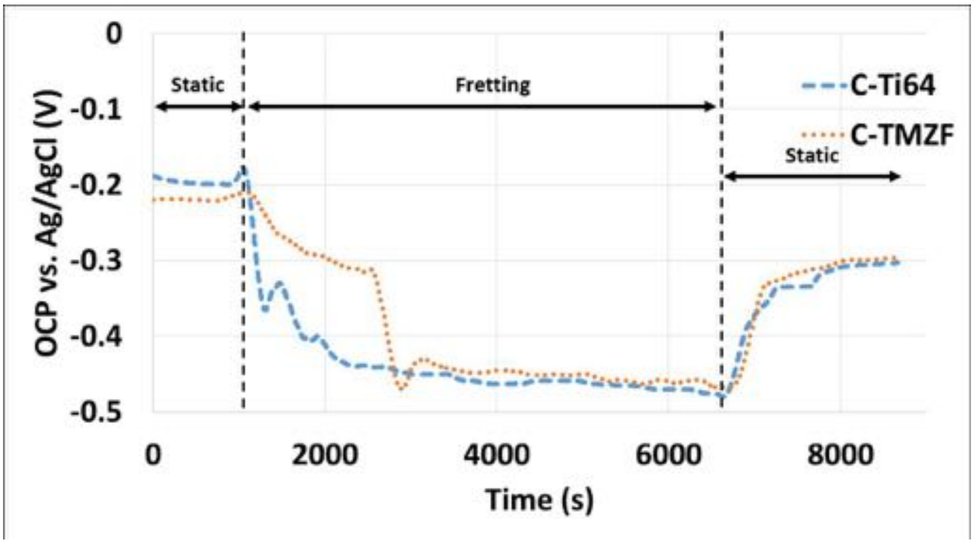

Figure 2

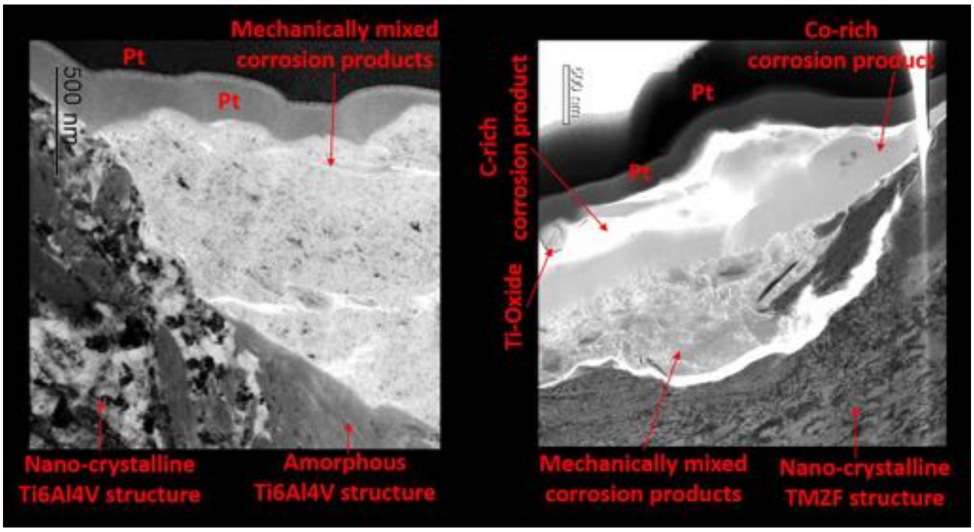
Mechanically mixed corrosion products
Pt
Pt
500 nm
Nano-crystalline Ti6Al4V structure
Amorphous Ti6Al4V structure
Co-rich corrosion product
Pt
Pt
C-rich corrosion product
Ti-Oxide
Mechanically mixed corrosion products
Nano-crystalline TMZF structure

Figure 3

#5723

Damage and Wear in Retrieved Humeral Inserts of Reverse Shoulder Joint Replacements: Where, How Much and Why?

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Introduction.

Reverse total shoulder replacements provide reliable improvement in shoulder function and pain relief for patients. Nevertheless, the survival of reverse total shoulder arthroplasty (rTSA) is lower compared to knee and hip replacements. Polyethylene wear and fatigue have been evaluated as complications in total joint replacements. In this regard scapular notching is associated with more clinical complications. Therefore the purpose of the study was to investigate the effect of scapular notching on polyethylene (PE) damage modes and also on linear and volumetric wear in retrieved rTSA humeral PE inlays contributing to failure of reverse shoulder replacements.

Material & Methods.

47 humeral polyethylene components were retrieved from revision surgery at a single institution. The total study population contains two subcohorts, which were used for the damage mode analysis and for the wear analysis, respectively. For the damage analysis 39 of the 47 humeral PE inlays were used. The extent and presence of wear damage modes in five defined zones were assessed by a modification of previously described grading systems for polyethylene joint replacements. For quantitative wear analysis the most frequent design (n=19) was chosen and linear and volumetric wear was determined using CMM method. Furthermore, pre-revision radiographs were analyzed for scapular notching. Finally, retrieval findings were correlated with clinical and radiographic data to identify risk of failures for these prostheses.

Results.

The components were implanted for a mean of 1.6 ± 2.6 years (range, 0.01 - 15.6 years). All humeral PE inlays showed some form of damage. Wear damage on the rim of the humeral PE inlays was more frequent and severe than in the intended articulation surface. Irrespective of the damage mode, the inferior rim zone sustained the greatest amount of wear damage followed by the posterior zone. Burnishing, Scratching, Pitting and Embedded Particles are most likely to occur in the articular surface area, whereas Surface Deformation, Abrasion, Delamination and Gross Material Degradation are predominantly present in the inferior and posterior rim zones. The mean total volume loss of all CMM measured components was 567.91 mm^3 ± 813.14 mm^3 and the mean linear wear depth varied from 0.06 to 12.51 mm. However, if the notched and non-notched components were compared a significant higher wear volume (947.32 ± 973.60 mm^3) was found for the notched components compared to the non-notched group (90.52 ± 60.72 mm^3). Generally, there were significantly greater incidence of damage and greater amount of wear if rim damage occurred.

Discussion and Conclusion.

The notched components showed a ten-fold increase in polyethylene wear. Therefore scapular notching has a strong effect on polyethylene damage and wear (Fig. 1). If scapular notching can be clinically avoided, the PE wear performance is in a similar magnitude as found for hip and knee replacements.

Keywords. Retrievals, reverse total shoulder arthroplasty, wear, PE inlays, Scapular Notching

Figures

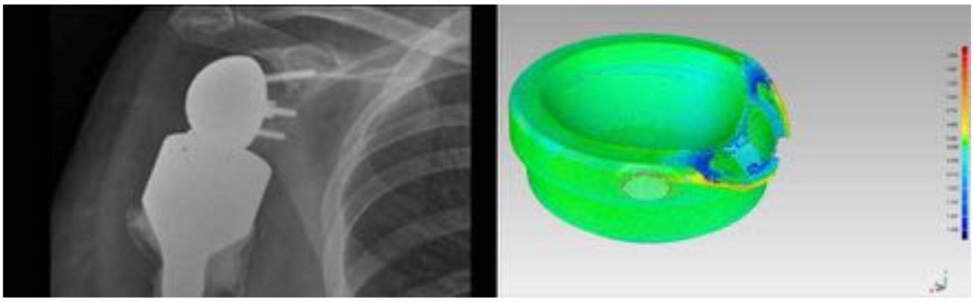

Figure 1

#5999

Development and Application of a Computational TKA Evaluation Framework for Preclinical Parametric Studies

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Development and application of a computational TKA evaluation framework for preclinical parametric studies

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Abstract

Background

Aseptic loosening is the leading cause of total knee arthroplasty (TKA) failure in the long term, of which osteolysis from polyethylene wear debris remains a problem that can limit the lifetime of TKA past the second decade. To help speed up design innovations, our goal was to develop a computational framework that could efficiently predict the effect of many sources of variability on TKA wear—including design, surgical, and patient variability.

Methods

We developed a computational framework for predicting TKA contact mechanics and wear. The framework accepts multiple forms of input data: patient-specific, population-

specific, or standardized motions and forces. CAD models are used to create the FEA mesh. An analytical wear model, calibrated from materials testing (wheel-on-flat) experiments, is fully integrated into the FEA process. Isight execution engine runs a design of experiments (DOE) analysis with an outcome variable, such as volumetric wear, to guide statistical model output. We report two DOE applications to test the utility of the computational framework for performing large variable studies in an efficient manner: one to test the sensitivity of TKA wear to the femoral center of rotation, and the second to test the sensitivity of TKA wear to gait input perturbations.

Results

Using this method, we demonstrated that choice of femoral center of rotation matters, and that although volumetric wear was most sensitive to variation in flexion/extension peaks, no one kinematic factor dominates TKA volumetric wear variability.

Conclusion

The two DOE applications represent initial first attempts to study variability in component alignment and input waveforms across large solution spaces. The computational framework will be most useful if it can be used in a TKA design setting, where new innovations can be tested as soon as they are developed to see if they are worthy of further mechanical testing.

Development of a Pre-Operative Planning Computation Tool to Simulate Virtual Surgery, Predicting Post-Operative Results

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Currently, hip implant designs are evaluated experimentally using mechanical simulators or cadavers, and total hip arthroplasty (THA) postoperative outcomes are evaluated clinically using long-term follow-up. However, these evaluation techniques can be both costly and time-consuming. Neither can provide an assessment of post-operative results at the onset of implant development. More recently, a forward-solution mathematical model was developed that functions as theoretical joint simulator, providing instant feedback to designers and surgeons alike. This model has been validated by comparing the model predictions with kinematic results from fluoroscopy for both implanted and non-implanted hips and kinetics from a telemetric hip. The model allows surgical technique modifications and implant component placement under in vivo conditions.

The objective of this study was to further expand the capabilities of the model to function as an intraoperative virtual surgical tool (Figure 1). This new module allows the surgeon to simulate surgery, then predict, compare, and optimize postoperative THA outcomes based on component placement, sizing choices, reaming and cutting locations, and surgical methods.

This virtual surgery tool simulates the quadriceps, hamstring, gluteus, iliopsoas, tensor fasciae latae, and an adductor muscle groups, as well as the hip capsular ligament groups. The model can simulate resecting, weakening, loosening, or tightening of soft tissues based on surgical techniques. Additionally, the model can analyze a variety of activities, including gait and deep flexion activities.

Initially, the virtual surgery module offers theoretical surgery tools that allow surgeons to alter surgical alignments, component designs, offsets, as well as reaming and cutting simulations. The virtual model incorporates a built-in CT scan bone database which will assist in determining muscle and ligament attachment sites as well as bony landmarks. The virtual model can be used to assist in the placement of both the femoral component and the acetabular cup (Figure 2).

Moreover, once the surgeon has decided on the placements of the components, they can use the simulation capabilities to run virtual human body maneuvers based on the chosen parameters. The simulations will reveal force, contact stress, and motion predictions of the hip joint (Figure 3). The surgeon can then choose to modify the positions accordingly or proceed with the surgery.

This new virtual surgical tool will allow surgeons to gain a better understanding of possible post-operative outcomes under pre-operative conditions or intra-operatively. Simulations using the virtual surgery model has revealed that improper component placement may lead to non-ideal post-operative function, which has been simulated using the model. Further evaluation is ongoing so that this new module can reveal more information pre-operatively, allowing a surgeon to gain ample information before surgery, especially with difficult and revision cases.

Figures

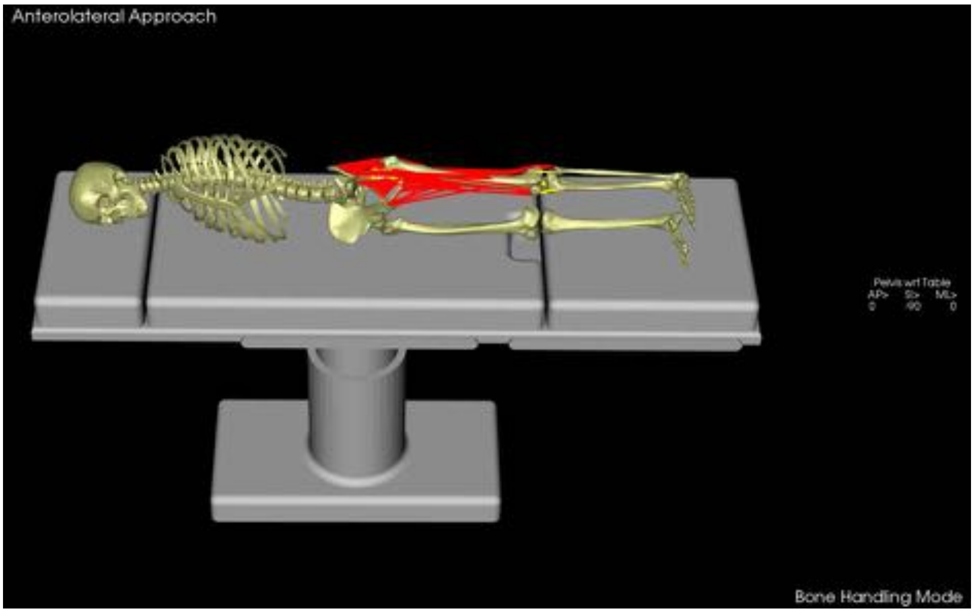

Figure 1

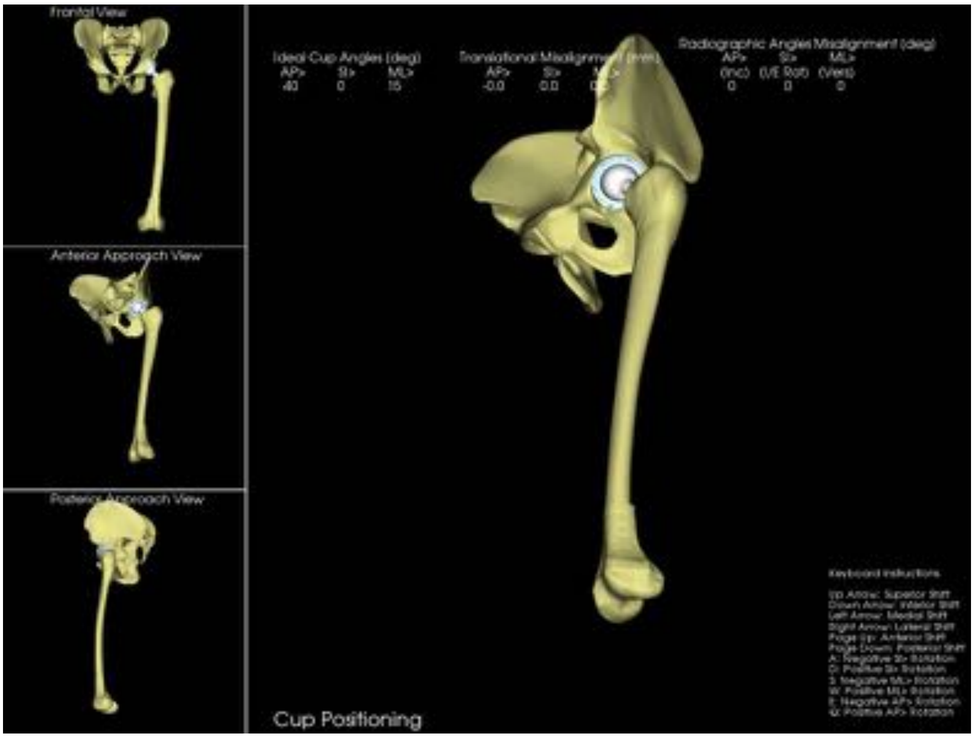

Figure 2

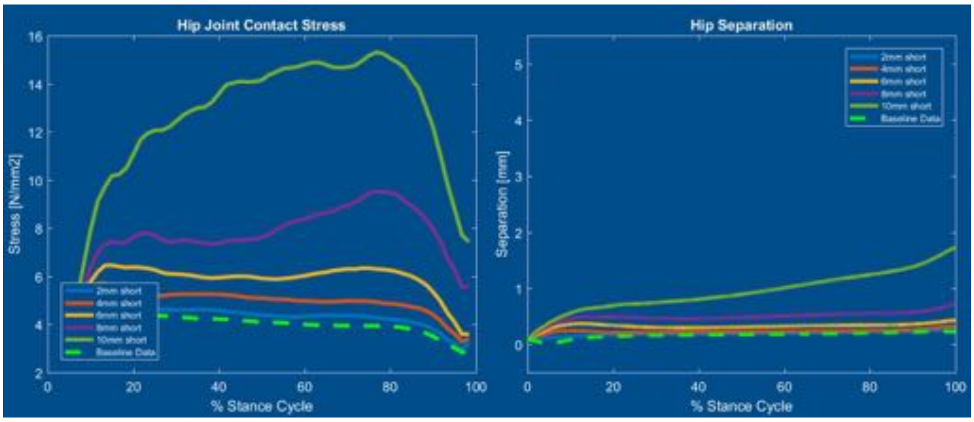

Figure 3

#5969

Use of a Mandatory Clinical Decision Unit Reduces Readmission Rates Following Total Joint Arthroplasty

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Introduction

In 2012 the Centers for Medicare & Medicaid Services (CMS) implemented the Hospital Readmission Reduction Program to reduce hospital readmission rates. Under this system, CMS retroactively assesses significant monetary penalties based upon hospital readmission rates. In 2016, nearly all hospitals in Michigan were subject to these penalties.

When postoperative TJA patients present to the emergency room, orthopaedic staff may be offsite or unavailable to immediately assist with medical decision making. This may lead to unnecessary hospitalization. It was hypothesized that by keeping patients in an Emergency Department Clinical Decision Unit (CDU) until they could be directly evaluated by the orthopaedic team, there would be a reduction in the readmission rate after TJA at our institution.

Methods.

As a quality initiative project, Providence and Providence Park hospitals in Southfield and Novi, Michigan mandated use of the CDU Program for all potential orthopaedic readmissions. A retrospective chart review was done on 365 patients that presented to the Emergency Department at Providence-Providence Park Hospital after either total hip or total knee arthroplasty. Patients presenting in the year prior to the implementation of the CDU Program were compared to patients presenting in the year after implementation. Prespectively collected data from the Michigan Arthroplasty Registry Quality Collaborative Initiative (MARCQI) including: demographics, length of stay (LOS), co-morbidities, and 30-day readmission rates were recorded. Fischer's test was done to assess categorical data and a student's t-test was used to compare age, BMI, and LOS.

Results.

There were no significant differences in age or sex between groups. There were some differences between groups Before and after CDU. After initiation of the CDU knee patients had a lower BMI ($p=0.024$) (no difference for hips), there was a shorter LOS in all joint patients ($p<0.05$), more hips patients did not have diabetes (33 before v. 56 after; $p=0.01$), fewer patients never smoked ($p<0.005$), and in knees there were fewer current smokers ($p<0.0001$). There was no difference in the number of CDU visits in knee patients, but there was a significant increase in hip CDU visits after the CDU began ($p=0.038$). Most importantly, after initiation of the CDU there were fewer readmissions after the initiation CDU for all joint patients ($p<0.05$).

Discussion

Hospital readmissions are costly and not always appropriate. Assessment by an orthopaedic surgeon prior to readmission was expected to decrease the number of unnecessary readmissions. To accomplish this, the CDU was used as a "holding area" to allow for a complete orthopaedic evaluation prior to readmission. During the first year of the CDU Project, we significantly reduced readmission rates following TJA. This study suggests that the implementation of similar initiatives may improve medical decision-making, help limit readmissions to those that are “appropriate,” and potentially save significantly in cost to the healthcare system and readmission penalties to the hospital.

Figures

Table 1. Demographics and length of stay

	Knees					Hips				
Demographics	**Before CDU**	**SE**	**After CDU**	**SE**	**p**	**Before CDU**	**SE**	**After CDU**	**SE**	**p**
Age	67.42	± 0.97	68.23	± 0.76	**0.257**	67.13	± 1.66	65.3	± 1.5	**0.21**
n	95		163			46		61		
Male (%)	27 (28.42)		51 (31.29)		**0.68**	23 (50.00)		22 (36.07)		**0.17**
Female (%)	68 (71.58)		112 (68.71		**0.68**	23 (50.00)		39 (63.93)		**0.17**
BMI	34.46	± 0.75	32.62	± 0.55	* **0.024**	30.79	± 1.06	29.42	± 0.88	**0.36**
LOS	2.01	± 0.10	1.80	± 0.08	* **0.045**	2.17	± 0.15	1.8	± 0.12 *	**0.03**

Figure 1

Table 2. Comorbidities.

	Knees			Hips		
Comorbidities	**Before CDU**	**After CDU**	**p**	**Before CDU**	**After CDU**	**p**
Smoking						
Never	9	78	* **<0.0001**	5	22	* **0.003**
Previous	46	71	**0.52**	25	30	**0.70**
Current	40	14	* **<0.0001**	16	9	**0.02**
Pre-Op EtOH						
No	39	68	**1.00**	17	24	**0.84**
Yes, <= 1 drink/week	38	57	**0.43**	23	25	**0.43**
Yes, 2 - 7 drinks/week	13	26	**0.72**	3	7	**0.51**
Yes, >= 8 drinks/week	5	12	**0.61**	3	5	**1.00**
Bleeding Disorder	0	4	**0.30**	0	1	**1.00**
History Of Dvt Pe	9	14	**0.82**	3	8	**0.34**
Diabetes Mellitus						
No	74	126	**1.00**	33	56	* **0.01**
Type 1	3	4	**0.71**	3	0	**0.08**
Type 2	18	33	**0.87**	10	5	**0.05**

Figure 2

Table 3. Readmission rate before and after the initiation of the CDU.

	Knees			Hips		
	Before CDU	**After CDU**		**Before CDU**	**After CDU**	
ER Visits	95	163		46	61	
ER Readmissions	26	7	* **<0.0001**	14	6	* **0.011**
CDU Visits	16	23	**0.591**	2	11	* **0.038**
Obs Visit	4	6	**1.000**	0	5	**0.069**
CDU/Obs Admit	0	0	**1.000**	0	0	**1.000**

Figure 3

#5782

Perioperative Surgical Home Model With or Without Electronic Medical Record Integration Results in Positive Clinical and Financial Outcomes

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Introduction: Total joint arthroplasty (TJA) is projected to be the most common elective surgical procedure in the coming decades, however TJA now accounts for the largest expenditure per procedure for Medicare and Medicaid provided interventions. This is coupled with increasing complexity of surgical care and concerns about patient satisfaction. The Perioperative Surgical Home (PSH) model has been proposed as a method to both improve patient care and reduce costs. The PSH model provides evidence-based protocols and pathways from the time of surgical decision to after postoperative discharge. PSH pathways can further be standardized with integration into electronic medical records (EMRs). The purpose of this study is to see if the implementation of PSH with and without EMR integration effects patient outcomes and cost.

Methods: A retrospective review was performed for all patients who underwent elective primary total joint arthroplasty at our institution from January 1, 2012 to April 1, 2018. Three cohorts were compared. The first cohort included patients before the implementation of the PSH model (January 1, 2012 - December 31, 2014). The second cohort included patients in the PSH model without EMR integration (January 1, 2015 – August 1, 2016). The third cohort included patients in the PSH model with EMR integration (August 1, 2016 - April 1, 2018). The clinical outcome criteria measured were average hospital length of stay (LOS), 30-day readmission rates, and discharge disposition. Financial data was collected and included average direct cost, implant cost, and estimated net revenue.

Results: Overall, 3,384 primary total joint arthroplasty cases were included. In the first cohort, before the implementation of the PSH, average LOS was 3.61 days, discharge to a skilled nursing facility (SNF) was 30.7%, and discharge to home care was 67.8%. Readmission data was unavailable due to switching to a new recording system. Implementation of a PSH without EMR integration decreased average LOS by 46.8% (1.92 vs. 3.61), decreased discharge to SNF by 51.8% (14.8% vs. 30.7%) and increased discharge to home care by 19.6% (84.3% vs. 67.8%). Implementing EMR integration further decreased the average LOS by 10.4% (1.72 vs 1.92), 30-day readmission decreased by 8.3% (2.2% vs. 2.4%), discharge to SNF decreased by 2.7%, and discharge to home care increased by 1%. Before the PSH model, the average direct cost was $10,778 per procedure, and average estimated net revenue was $16,146. Implementation of the PSH without EMR integration decreased direct cost by 2.1% ($10,434 vs. $10,778). Implementation of the PSH with EMR integration decreased direct cost by 5.2% ($10,217 vs. $10,778).

Conclusions: The implementation of a PSH model for total joint arthroplasty, especially with electronic medical record integration, reduces direct cost, average LOS, 30-day readmissions, and increases discharge to home care.

#5702

Safety Criteria for Short Stay After Total Joint Replacement

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Background: There is a recent interest and focus on reducing the length of stay and early discharge after total joint replacement (TJR). However, safety criteria for same-day (SD) or next-day (ND) home discharge are not well defined. We implemented a screening questionnaire to identify patients that qualify for early home discharge. The aim of this study was to assess the efficiency of this questionnaire and short-term outcomes including re-admission and peri-operative complications after TJR.

Methods: Between January 2016 and July 2017, 423 consecutive primary hip and knee arthroplasties were performed by the two senior surgeons at our institution. All cases were followed for a minimum of 3-month prospectively after institutional review board approval. Patients were divided based on using a pre-operative questionnaire to determine their disposition after surgery. Group 1 includes 121 cases as control and group 2 includes 302 cases with pre-operative questionnaire. Spinal anesthesia and multimodal pain management including peri-articular injection was used in all cases.

The pre-operative questionnaire (PQ, Swiftpath, Inc) included an overall score based on age, comorbidities, body mass index, physical assessment, motivation, comprehension, family support, home setup (i.e. easy access/stairs), proximity to the hospital and lack of serious barriers to early home discharge. Patients were divided into 3 categories based on the score: SD/ND home, regular home discharge and rehabilitation/subacute nursing facility (SNF) discharge. Length of stay (LOS), post-operative complications, readmissions, and discharge destination were assessed. Correlation the questionnaire score and outcomes were assessed.

Results: In group 1, 29% of the patients were discharged home after minimum 2 days after surgery with home services and 71% were discharged to short- or long-term rehabilitation center. The mean length of stay was 4.6 ± 2.5 days (range 2 to 7 days). 3% had symptomatic DVT and one patient pulmonary embolism during hospital stay, all after total knee arthroplasty. There was one re-operation for acute periprosthetic infection (0.8%), two cardiopulmonary events (1.6%), and 4 other ER visits for inadequate pain control (3%).

In group 2, 51% of the patients were discharged home, 6% of which (10 patients) were same-day discharge. The mean length of stay was 2.2 ± 0.8 days (range 0 to 5 days). One patient (1%) had symptomatic DVT. There were 5 (1.6%) ER visits for wound concerns and pain. There were no acute re-admissions, infections or re-operations.

Conclusions: Implementation of a screening questionnaire for SD/ND early discharge is safe and results in significant reduction of length of stay, higher discharge to home, lower rate of DVT/PE/cardiopulmonary complications and less ER visits.

#6068

Provision of Prehabilitation and ROM Prior to Total Knee Arthroplasty

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Introduction & aims

Face-to-face prehabilitation prior to total knee arthroplasty (TKA) has been previously shown to influence range of motion following TKA, [1] but does not see widespread implementation due to the costs involved. Digital mobile applications are a promising tool to administer prehabilitation in a more cost effective manner. This study investigates whether provision of prehabilitation through a remote mobile digital application is effective in improving passive range of motion prior to TKA.

Method

A retrospective analysis was performed on a consecutive case series of 103 patients who underwent TKA by a single surgeon from September 2016 to March 2018. The first 71 patients did not undergo prehabilitation. The following 32 patients were offered digital prehabilitation through a mobile application called PhysiTrack. Using Physitrack, patients were monitored by a physiotherapist, and exercises were modified based on pain levels or co-morbidities. Patients were reminded to complete their exercise program on a daily basis. At surgery, the OmniNav system was used to assess maximum extension and flexion pre and post implantation as per the surgeon's standard technique and the data extracted for analysis. All patients underwent TKA using identical surgical technique and peri-operative care.

Results

Of the 103 patients investigated in this study, the average age was 68.1 +/- 7.8 years in which 51% (53) were female. There were no significant differences in these population characteristics between the two groups. Mean passive maximum extension and flexion prior to implantation was 1.5° (± 5.4) flexion and 129.4° (± 6.7) respectively. Post implantation, mean passive maximum extension and flexion was 1.3° (± 5.4) hyper-extension and 127.7° (± 7.8) respectively. The flexion means were not significantly different pre and post implantation but the extension means were (p=0.0002).

There was a statistically significant difference in maximum flexion between the group of patients who received prehabilitation and those who did not, with the prehabilitation group being capable of more flexion on average (131.8° (± 7.0) vs 128.3 (± 6.3), difference of 3.5°, p=0.0174). When considering a threshold of at least 130° passive flexion reached preoperatively, 22/32 (68.7%) of the prehabilitation knees reached the threshold, while only 27/71 (38.0%) of the non prehabilitation knees did and this difference was statistically significant. (p = 0.0074) No statistically significant differences were observed for the flexion and extension post-implantation.

Conclusions

In this study, it has been shown that prehabilitation implemented as a digital, application driven programme has increased ROM of patients prior to surgery, although no impact on postoperative ROM and clinical outcomes has yet been shown. Further research into short and medium term postoperative clinical outcomes is called for. Digital provision of pre- and rehabilitation may be a cost effective way to implement meaningful physiotherapy programmes for TKA patients.

1. Matassi F, Duerinckx J, Vandenneucker H, Bellemans J. Range of motion after total knee arthroplasty: the effect of a preoperative home exercise program. Knee Surg Sports Traumatol Arthrosc 22(3): 703, 2014

Figures

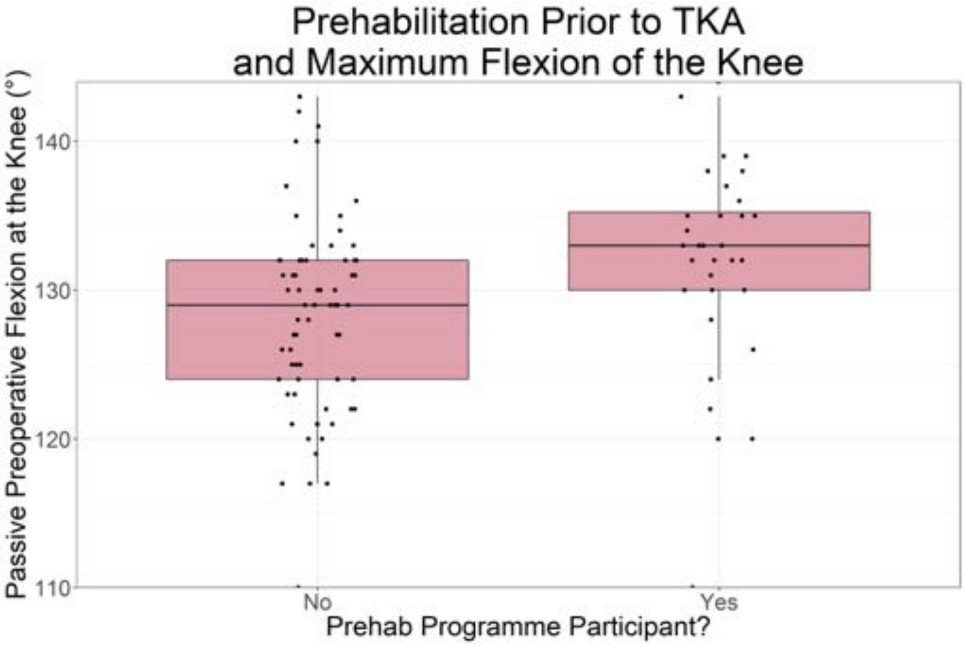

Figure 1

#5827

A Unique Cardiac Screening Program to Reduce Readmissions in Risk Bundled Total Hip and Knee Replacement Patients

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Background

The Bundled Payments for Care Improvement (BPCI) was developed by the US Center for Medicare and Medicaid (CMS) to evaluate a payment and service delivery model to reduce cost but preserve quality. 90 day postoperative expenditures are reconciled against a target price, allowing for a monetary bonus to the provider if savings were achieved. The surgeon is placed in a position to optimize the patients preoperatively to minimize expensive postoperative cardiovascular readmissions in a high risk population. Traditionally, surgeons request that primary care providers medically clear the patient for surgery with or without additional cardiology consultation, without dictating specific testing. Typical screening includes an EKG, occasionally an echocardiogram and nuclear stress test, and rarely a cardiac catheterization. Our participation in the BPCI program for total hip and knee replacement surgeries since 1/1/15 has demonstrated a significant number of patients having readmissions for cardiac events.

Objective

To determine the medical effectiveness and cost savings of instituting a new innovative cardiac screening program *(Preventive Cardio-Orthopaedics)* for total hip and knee replacement patients in the BPCI program and to compare result to those managed in the more traditional fashion.

Methods

The new screening program was instituted on 11/1/17 directed by an advanced cardiac imaging cardiologist (EH). Testing included an electrocardiogram, echocardiogram, carotid and abdominal ultrasound, and coronary computed tomography angiography (CCTA). If needed, a 3 day cardiac rhythm monitor was also performed. Four of the ten physicians in our group performing hip and knee replacement surgeries participated. Charts of readmitted patients were reviewed to determine past medical history, method of cardiac clearance, length and cost of readmission.

Results

1,361 patients had total hip or knee replacement in the BPCI program between 1/1/15 and 1/28/18 and all had complete 90 day postoperative readmission data supplied by the CMS, with 25 of these patients evaluated through the *Preventive Cardio-Orthopaedics* program. 12 (0.90%) screened via the traditional cardiac program had a cardiac event readmission. The average readmission hospital stay was 3.67 days at a total cost of $69,378. 7 of 12 had a preoperative clearance by a cardiologist. In 9 of the 12 patients, the only preoperative cardiac screening tool performed was an electrocardiogram.

None of these 25 patients evaluated through the new program has been readmitted. 84 more patients have been evaluated in this program since 1/28/18, but 90 day readmission data is still incomplete. Preliminary data suggests that the highest risk in these patients is not severe coronary artery disease, but atrial fibrillation, hypertension with left ventricular hypertrophy, and cardiac plaques with ulceration.

Conclusions

Risk sharing programs have forced joint replacement surgeons to take a more active role in optimizing their patients medically; otherwise they will be penalized with a decreased reimbursement. Traditionally, we have abdicated this responsibility to primary care and cardiology physicians but have noted a high readmission risk with a cardiac event. In response, we have begun using a unique cardiac screening model. Our preliminary experience predicts fewer cardiac readmissions thereby improving care, and at a lower cost.

#6025

Wearable Sensor Technology and Machine Learning as a Tool for Assessing Patient Recovery

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Introduction & Aims – Patient recovery after total knee arthroplasty remains highly variable. Despite the growing interest in and implementation of patient reported outcome measures (e.g. Knee Society Score, Oxford Knee Score), the recovery process of the individual patient is poorly monitored. Unfortunately, patient reported outcomes represent a complex interaction of multiple physiological and psychological aspects, they are also limited by the discrete time intervals at which they are administered. The use of wearable sensors presents a potential alternative by continuously monitoring a patient's physical activity. These sensors however present their own challenges. This paper deals with the interpretation of the high frequency time signals acquired when using accelerometer-based wearable sensors.

Method – During a preliminary validation, five healthy subjects were equipped with two wireless inertial measurement units (IMUs). Using adhesive tape, these IMU sensors were attached to the thigh and shank respectively. All subjects performed a series of supervised activities of daily living (ADL) in their everyday environment (1: walking, 2: stair ascent, 3: stair descent, 4: sitting, 5: laying, 6: standing). The supervisor timestamped the performed activities, such that the raw IMU signals could be uniquely linked to the performed activities. Subsequently, the acquired signals were reduced in Python. Each five second time window was characterized by the minimum, maximum and mean acceleration per sensor node. In addition, the frequency response was analyzed per sensor node as well as the correlation between both sensor nodes. Various machine learning approaches were subsequently implemented to predict the performed activities. Thereby, 60% of the acquired signals were used to train the mathematical models. These models were than used to predict the activity associated with the remaining 40% of the experimentally obtained data.

Results – An overview of the obtained prediction accuracy per model stratified by ADL is provided in Table 1. The *Nearest Neighbor* and *Random Forest* algorithms performed worse compared to the *Support Vector Machine* and *Decision Tree* approaches. Even for the latter, differentiating between walking and stair ascent/descent remains challenging as well as differentiating between sitting, standing and laying. The prediction accuracies are however exceeding 90% for all activities when using the *Support Vector Machine* approach. This is further illustrated in Figure 1, indicating the actual versus predicted activity for the validation set.

Conclusions – In conclusion, this paper presents an evaluation of different machine learning algorithms for the classification of activities of daily living from accelerometer-based wearable sensors. This facilitates evaluating a patient's ability to walk, climb or descend stairs, stand, lay or sit on a daily basis, understanding how active the patient is overall and which activities are routinely performed following arthroplasty surgery. Currently, effort is undertaken to understand how participation in these activities progresses with recovery following total knee arthroplasty.

Figures

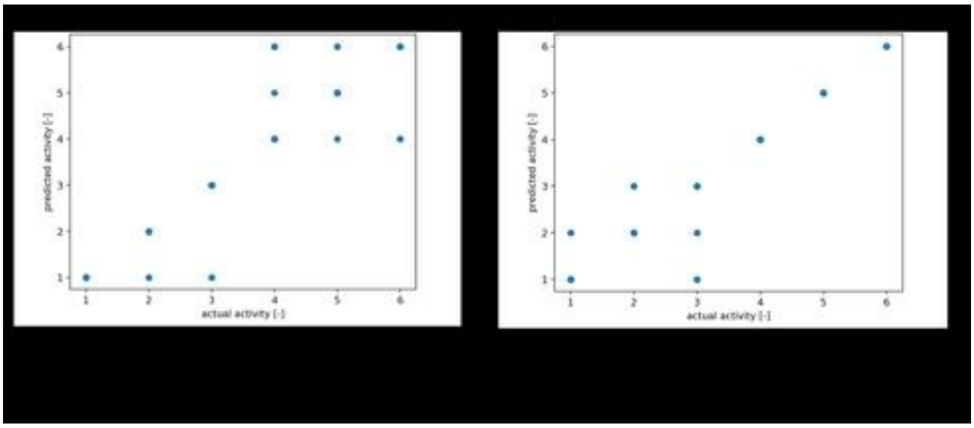

Figure 1

Figure 2

#5882

Small Data Forecasting of Length of Stay After Primary Total Hip Arthroplasty in the Value-Based Payment Era: Validation of a Predictive Big Data Machine Learning Model

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Background: The advent of value-based conscientiousness and rapid-recovery discharge pathways presents surgeons, hospitals, and payers with the challenge of providing the same total hip arthroplasty episode of care in the safest and most economic fashion for the same fee, despite patient differences. Various predictive analytic techniques have been applied to medical risk models, such as sepsis risk scores, but none have been applied or validated to the elective primary total hip arthroplasty (THA) setting for key payment-based metrics. The objective of this study was to develop and validate a predictive machine learning model using preoperative patient demographics for length of stay (LOS) after primary THA as the first step in identifying a patient-specific payment model (PSPM).

Methods: Using 229,945 patients undergoing primary THA for osteoarthritis from an administrative database between 2009-16, we created a naïve Bayesian model to forecast LOS after primary THA using a 3:2 split in which 60% of the available patient data “built” the algorithm and the remaining 40% of patients were used for “testing.” This process was iterated five times for algorithm refinement, and model performance was determined using the area under the receiver operating characteristic curve (AUC), percent accuracy, and positive predictive value. LOS was either grouped as 1-5 days or greater than 5 days.

Results: The machine learning model algorithm required age, race, gender, and two comorbidity scores (“risk of illness” and “risk of morbidity”) to demonstrate excellent validity, reliability, and responsiveness with an AUC of 0.87 after five iterations. Hospital stays of greater than 5 days for THA were most associated with increased risk of illness and risk of comorbidity scores during admission compared to 1-5 days of stay.

Conclusions: Our machine learning model derived from administrative big data demonstrated excellent validity, reliability, and responsiveness after primary THA while accurately predicting LOS and identifying two comorbidity scores as key value-based metrics. Predictive data has the potential to engender a risk-based PSPM prior to primary THA and other elective orthopaedic procedures.

Figures

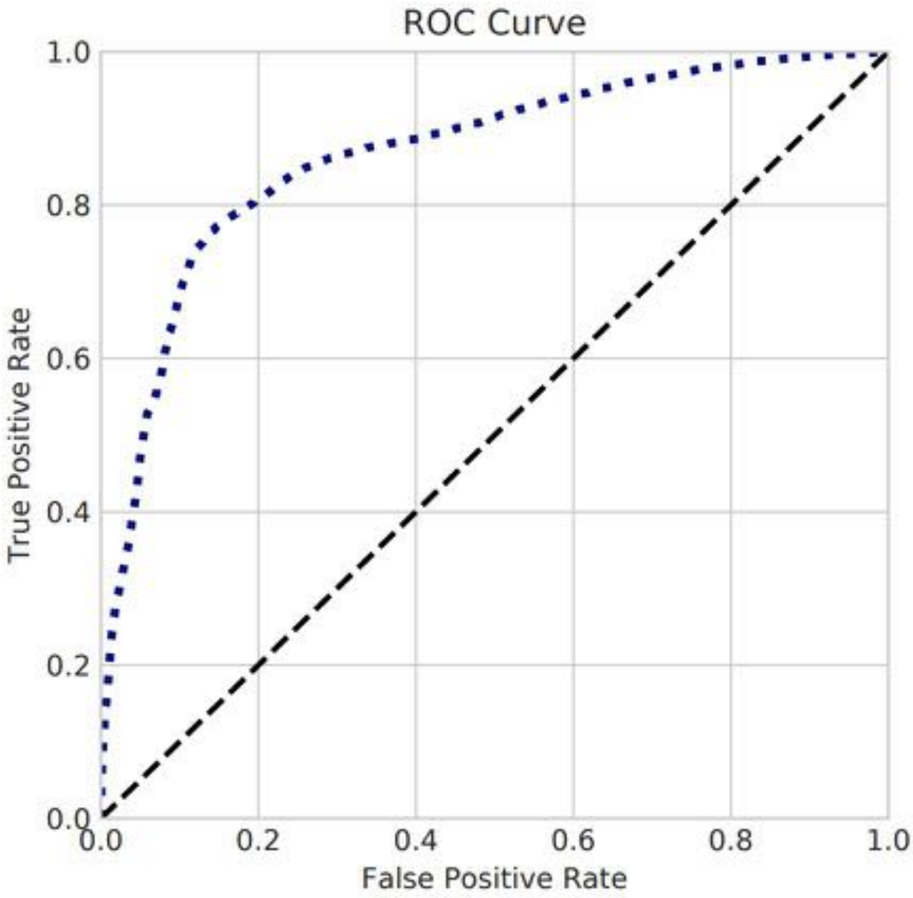
ROC Curve
1.0
0.8
0.6
0.4
0.2
0.0
True Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
False Positive Rate

Figure 1

#5888

Development of an Augmented Reality Rehabilitation Platform in Shoulder Arthroplasty

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BACKGROUND:

Telerehabilitation has been shown to both promote effective recovery after shoulder arthroplasty and may improve adherence to treatment. Such systems require demonstration of feasibility, ease of use, efficacy, patient and clinician satisfaction, and overall cost of care, and much of this data has yet to be provided. Few augmented reality rehabilitation approaches have been developed to date. Evidence suggests real-time reality rehabilitation may be equivalent to conventional methods for adherence, improvement of function, and relief of pain seen in these musculoskeletal conditions. We proposed that the use of an augmented reality rehabilitation platform during the postoperative period (including post-shoulder arthroplasty) may be able to track patient activity and range of motion as well as promote recovery.

METHODS:

A prototype augmented reality platform equipped with a motion sensor system optimised for the upper arm was developed to be used to validate 4 arcs of shoulder motion and complete directed upper arm exercises designed for post-shoulder arthroplasty rehabilitation was built and tested. This system combined augmented reality instructions and motion tracking to follow patients over the course of their therapy, along with a telehealth patient-clinician interface.

FINDINGS:

The augmented reality platform was tested to validate shoulder range of motion examination similar to that of standard goniometer measurements. Healthy test subjects without shoulder pain or prior shoulder surgery performed the arcs of motion for 5 repetitions as part of a home therapy program. Each motion was measured with angular measurements as a proof of concept with good precision (mean 4.2 degrees +/- 2.1 degrees). Real-time patient-clinician interface testing was also conducted along with a therapy plan, as well as tracking of patient-reported outcome measures.

DISCUSSION:

Augmented reality systems that track patients' complex movements, including clinical shoulder range of motion, suggest the promising future of telerehabilitation in arthroplasty, particularly in telemonitoring before and after surgery. As this technology continues to gain acceptance, further studies that evaluate the outcomes of augmented reality rehabilitation for long-term followup are needed.

#5562

Cognitive Task Analysis in Virtual Reality Hip Arthroplasty Training

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Introduction

Understanding and training for the cognitive steps of a complex task improves performance in professional sport, aviation, and keyhole surgery. For total hip arthroplasty (THA), cognitive training prior to performing real surgery may be an effective adjunct alongside simulation to shorten the learning curve. Virtual Reality (VR) is an immersive digital environment, designed for experiences or gaming, but not conventionally for delivering knowledge or practicing *open* surgical skills. This study sought to create a CTA-based VR training tool to perform direct anterior approach (DAA) THA, validated by expert surgeons.

Methods

We employed a modified Delphi method with four expert surgeons from three international centres of excellence. Surgeons were independently observed performing THA. Using a semi-structured interview, surgeons then created a Task Diagram and completed a Knowledge Audit in the following domain: Diagnosing and predicting; situational awareness; perceptual skills; improvising; metacognition; recognizing anomalies; and compensating for equipment limitations. This qualitative data underwent thematic analysis by an independent reviewer to create a unified, anonymised CTA. This was sent as an electronic survey to the experts, to keep, eliminate or alter each statement in successive rounds, until a consensus was reached, before using this model to create a VR DAA-THA simulator.

Results

Experts reached 100% consensus after five rounds. They defined THA in 46 steps and 52 decision points in 8 distinct procedural phases. Each phase comprised of a set of actions, cognitive demands, and critical errors and strategies. These related to three general domains – patient-related technical demands, equipment-related technical demands, and non-technical demands. This CTA was mapped and validated onto a VR DAA-THA simulator, with each phase of the procedure linked to intra-operative steps.

Conclusions

This is the first validated CTA tool for arthroplasty, and the first to deploy CTA for an open procedure in virtual reality. This provides structure for competency-based learning of this complex procedure; and describes strategies to recognise and solve intra-operative challenges as derived from experts. The VR simulator therefore delivers education mapped to expert surgeons' technique.

Implications

This is the first, expert-derived, virtual reality arthroplasty training platform, designed to develop ‘bottom-up’ cognitive embodiment, with trainees learning psychomotor skills to create knowledge. Future work will compare its effectiveness to conventional ‘top-down’ training, in delivering procedural knowledge and ability.

#5570

Learning Computer-Assisted Total Knee Arthroplasty: A Cusum Analysis on Ten Surgeons

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INTRODUCTION

Successful adoption of computer-assisted orthopaedic surgery (CAOS) system in total knee arthroplasty (TKA) should demonstrate both superior outcomes and reasonable learning effort. Studies investigating the impact of learning on surgical efficiency (time) either assumed learning duration (number of cases), or performed regression on surgical time from the initial case series. However, as surgical time is often noisy in nature, it can be challenging to identify the learning phase from the regression.

Cumulative sum control chart (CUSUM) has been widely applied in industry to assess the stabilization of a production process, and proven to be an objective and effective tool to evaluate the learning process in other medical fields. The goal of this study was to adopt this advanced methodology to define the learning period of a contemporary CAOS system.

Materials and Methods

Technical records on the CAOS TKAs performed by 10 surgeons (7 senior CAOS surgeons, 3 novice surgeons with no prior CAOS experience) were reviewed. CUSUM analysis on surgical time (system usage time) was performed for each surgeon on his/her first 50 cases. The cumulative sum of deviances [1] was plotted in chronological order for each surgeon. The beginning of a horizontal trend in the plot signified the stabilization of the process, therefore the associated case number (cases to proficiency: CP) was identified as the end of learning. The CP was compared between the senior and the novice CAOS surgeons. The difference in surgical time was compared between the cases in the learning curve (from case #1 to #CP) and the later cases (#41-50). Significance was defined as $p<0.05$.

Results

Compared to the actual surgical time graph, the CUSUM plot clearly exhibited three unique phases, with Phase II demonstrating stabilization of the process (Fig 1). The shape of the 3 Phases was surgeon-specific, reflecting individual characteristics of learning. On average, it took 12-13 cases to finish learning the CAOS system, with no substantial difference between senior and novice surgeon groups (Table 1). Both senior and novice surgeon groups spent ~15min more during their learning phase (cases #1-#CP) than their last 10 cases in the series (#41-#50) (Table 1). No significant difference was found between senior and novice surgeons in learning duration (CP) and time increase during learning.

Discussion

This study applied CUSUM to analyse learning curve of a CAOS system, relating the adoption of CAOS as a process that eventually stabilizes with mastery of the task. The data suggested that the average learning of the system studied took 12-13 cases, irrelevant to surgeons CAOS experience. Compared to cases performed after learning, the learning phase only moderately increased surgical time. Having no CAOS experience before adopting this system did not result in substantially steeper learning curve.

Despite being applied to various medical fields, CUSUM is under-recognized and under-utilized in orthopedics. Adoption of this advanced method not only provides improved understanding of CAOS TKA learning in general, but also allows exploration on differences in learning between individual surgeons or surgeon characteristics.

REFERENCES

[1] Bokhari, et al. Surg Endosc. 2011;25(3):855-60.

Figures

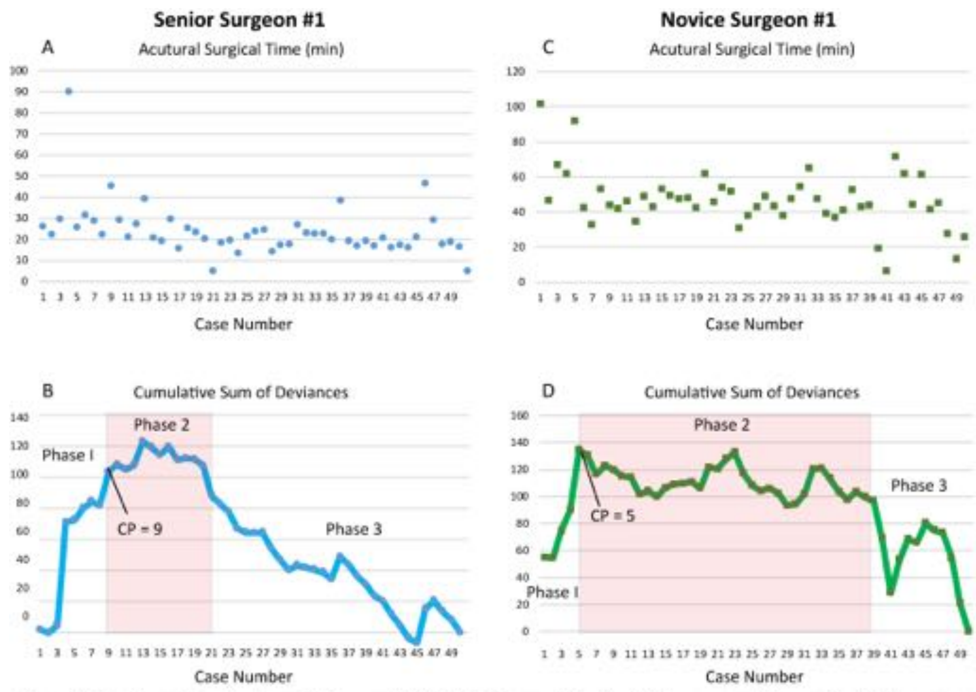

Figure 1. Graphs on the actual surgical time and CUSUM deviance charts for A, B) a representative senior CAOS surgeon, and C, D) a representative novice surgeon. The graph was plotted according to the chronological case numbers.

Figure 1

	Senior Surgeon	Novice Surgeon	Pooled
N	7	3	10
Cases to Proficiency (CP)	13.0 ± 7.1	12.0 ± 7.5	13.4 ± 7.4
Time Increase in Learning Curve (min)*	13.0 ± 8.6	16.2 ± 14.6	13.3 ± 10.7

* Calculated as *Average(cases #1 - #CP) - Average(cases #41-50)*

Table 1. Summary of learning characteristics in senior surgeon, novice surgeon, and pooled surgeon groups. No significant difference was found between senior and novice surgeons (N.S.) in CP and time increase.

Figure 2

#5563

When Are Patients Actually Driving After Minimally Invasive Anterior Hip Replacements and Total Knee Arthroplasty Surgery? a Single Surgeon Experience of 353 Joint Replacements.

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INTRODUCTION:

The primary goal of THA or TKA is to relieve pain and restore mobility.The success is determined by the longevity of prosthesis and early return to routine activities, such as driving. With enhanced recovery regimens, patients are being discharged within 24-48hrs post-op. Our aim was to determine when our patients returned to driving after anterior hip replacements and knee replacements.

METHODOLOGY:

This study included 207 soft tissue sparing anterior bikini THA and 146 patient specific instrumented (PSI) TKA between Feb 2017 and March 2018. All patients included weredriving before surgery. Non-drivers were excluded. A detailed questionnaire was sent to all patients 3 to 6 weeks after surgery to record their driving status. 50 patients were randomly selected to assess flexion at the hip, knee, and ankle joints whilst seated in the driver's seat of their vehicle.

RESULTS:

There were 213 females and 124 males (mean age of 69 years) and average BMI of 18.24. There were 207 THAs (99 left, 106 right and 1 bilateral one stage) and 146 TKAs (L=70 & R=76). 63.8% patients returned to driving within the first 3 weeks after surgery (Table 1) of which 32 patients (21 THAs and 11 TKAs) resumed driving within the first post-op week, 110 patients (69 THAs and 49 TKAs) drove in the second week and 73 (38 THAs and 38 TKAs) returned to driving in the third week. The rest of the 82 patients reports that they could have driven earlier but chose not to, since they had alternatives that they preferred. The earliest a patient resumed driving post-surgery was on the 2^{nd}day(Post THA and TKA) 96.4% stated that they were confident when they first resumed driving. There were 40 patients out of the total 337 that did not return to driving post-surgery. 3 (2 hips and 1 knee) were because of medical comorbidities and the rest 37 (14 hips and 6 knees) were because they had their children/spouses to drive for them but were confident that they could have driven themselves if need be.

There seemed to be no direct correlation between resumption of driving and the side of surgery. There were 282 patients driving automatic cars and 23 driving manual cars. Out of the manual car drivers, 8 were operated on the left side (5 hips and 3 knees), but still all confidently returned to driving within 6 weeks earliest returning within the 1st week. Post measurement of angles of flexion at hip, knee and ankle while accelerating and braking among 50 patients we found that ankle movements significantly affect driving more so than hip and knee.

CONCLUSION:

We found that after soft tissue sparing anterior bikini THA and PSI TKA, patients were driving as early as within a week with majority feeling confident and less apprehensive about recommencing driving, potentially due to enhanced recovery measures which were taken, including the minimally invasive surgical technique, local analgesia infiltration and early mobilization post procedure.

Figures

Table 1: Details of Return to Driving after THA and TKA.

Return to Driving	Hip				Knee			Grand Total
	Both Hips (One Stage Bilateral)	Left Hip	Right Hip	Hip Total	Left Knee	Right knee	Knee Total	
Yes	**1**	**83**	**85**	**169**	**66**	**62**	**128**	**297**
Started in 1st Week		13	8	21	6	5	11	32
Started in 2nd Week		32	34	66	23	21	44	110
Started in 3rd Week	1	14	21	36	15	22	37	73
Started in 4th week		8	11	19	10	4	14	33
Started in 5th Week		3	3	6	7	3	10	16
Started in 6th Week		7	5	12	1	5	6	18
Started after 6 Weeks		6	3	9	4	2	6	15
No		**16**	**13**	**29**	**6**	**5**	**11**	**40**
Did Not Return (Due to Medical Comorbidity)			1	1		2	2	3
Not Driving		16	12	28	6	3	9	37
Grand Total	**1**	**99**	**98**	**198**	**72**	**67**	**139**	**337**

Figure 1

#5564

Minimal Post Operative Restrictions Are Safe After Posterior Approach Total Hip Arthroplasty. Results From a Large Cohort Study.

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Background and purpose

To prevent early post-operative dislocation after total hip arthroplasty (THA) patients have to adhere to restrictions. More restrictive protocols are common if THA surgery is performed with the posterior approach, but scientific evidence supporting this is scarce. We aimed to compare the <90 day dislocation rate between patients managed with minimal versus extensive restrictions in a large cohort posterior approach THA's.

Methods

Prospective cohort (n=1049) of consecutive elective primary hip replacement surgery procedures (Sept 2014-Jul 2017) managed with minimal postoperative restrictions. Hospital charts were prospectively reviewed for patient demographics, risk factors and any hip dislocation. Control (n=1102) consecutive primary elective THA's (Jan 2011-Aug 2014) managed with a traditional restrictive protocol. See table 1 for overview of restrictions.The posterior surgical approach was used in all procedures.

Results

Minimal restrictions group: 17 dislocations <90 days (1.6%); Restricted group: 28 (2.5%), chi-square p=0.1. Testing the hypothesis of inferiority by a minimum of 1% increase in ≤90 day dislocation risk: p=0.14 (test for difference) and p<0.001 (non-inferiority test), allowing us to discard the null hypothesis (absolute increase in risk of ≥1% with minimal restrictions). Patient demographics were similar but the proportion of surgeries performed with a femoral head >28mm was higher in the minimal restrictions group. In the minimal restrictions group there were also more patients with a higher ASA classification and also more patients who received an uncemented total hip prosthesis. See table 1. Of the potential confounders only gender was significant, and the adjusted OR for short term dislocation in the minimal restrictions group was 0.67 which was still not significant. In the final logistic regression model only female sex was significant protective against short term dislocation. The adjusted OR's for large femoral head sizes and high surgeon volume were both >2, but failed to reach statistical significance. See table 2.

Interpretation

Patients can be managed safely with minimal restrictions after posterior approach THA if combined with frequent use of larger femoral heads.

Figures

Restricted group (n=1102)	Less restricted group (n= 1049)
Changed	
Sleeping supine for 6 weeks	No sleeping restrictions
Abduction pillow during hospital stay	Abduction pillow until first mobilization
Pillow at home	Pillow only for comfort
Hip flexion > 90°, internal rotation or hip adduction not allowed	Combined full hip flexion, internal rotation and adduction not allowed
Car driving after six weeks	Car driving allowed when walking without crutches
Elevated toilet seat	Normal toilet seat
Elevated chair	Normal chair
Crutches for 6 weeks	Crutches as needed
Unchanged	
No cross-legged sitting	No cross-legged sitting
Bending with the operated leg moved backwards	Bending with the operated leg moved backwards

Figure 1

Table 2, Patient and surgical demographics

	Less restricted Group (n=1049)	Restricted Group (n=1102)	P
Age (median, IQR)	69.0 (13.4)	69.1 (13.0)	0.527*
LOS (hours, median, IQR)	51.0 (13.5)	76.6 (25.1)	<0.001*
ASA (n, %)	Missing n=11	Missing n=14	
≤ 2	856 (82.5)	933 (85.8)	
3	182 (17.5)	155 (14.2)	0.038**
Gender (n, %)			
Male	397 (37.8)	403 (36.6)	0.541**
Female	652 (62.2)	699 (63.4)	
Diagnosis (n, %)			
Primary OA	1011 (96.4)	1068 (96.9)	
Secondary OA/AVN/RA	38 (3.6)	34 (3.1)	0.564**
Prosthesis fixation (n, %)			
Cemented	438 (41.8)	597 (54.2)	
Uncemented	597 (56.9)	495 (44.9)	<0.001**
Hybrid (not analysed)	14 (1.3)	10 (0.9)	
Femoral head diameter (n, %)			
28mm or less	443 (42.2)	594 (53.9)	
≥ 32mm	606 (57.8)	508 (46.1)	<0.001**

*Mann-Whitney U test; ** Pearson chi-square test

Figure 2

Table 3, Logistic regression analysis: adjusted odds ratio (OR) for dislocation

Risk factor for dislocation	OR (95% CI)	P
Minimal restrictions	0.67 (0.36-1.25)	0.21
Age	1.05 (1.00-1.09)	0.06
Female sex	0.36 (0.20-0.68)	>0.01
Femoral Head size 28mm or less	2.26 (0.96-5.31)	0.06
ASA 1	1.00 (0.47-2.14)	0.10
Diagnosis primary OA	0.56 (0.93-5.57)	0.45
Surgeon volume>100	2.27 (0.93-5.58)	0.74

Figure 3

#5950

Can Patients Practice Strenuous Sports After Uncemented Ceramic-on-Ceramic Total Hip Arthroplasty?

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Background: Patients are often concerned about return to sports following total hip arthroplasty (THA).

Purpose: We aimed to (i) evaluate sports participation and motivation rates in a large cohort of patients that received uncemented THA with ceramic-on-ceramic (CoC) bearings, (ii) determine whether patients' participation is associated with their motivation for each sport, pre-operative demographics, or patient-reported outcomes.

Methods: We surveyed 1310 patients that received uncemented ceramic-on-ceramic THA aged <75 and collected levels of motivation and participation for 22 different sports as well as PROMs. A total of 1042 patients (1206 hips) returned questionnaires, aged 60.6±8.8 years at index surgery.

Results: 51% participated regularly or frequently in at least one light sport, 73% in at least one moderate sport, and 20% in at least one strenuous sport. Participation was strongly correlated with motivation ($r=0.97$, $p<0.001$) (Figure 1), but not with level of discomfort ($r=0.22$, $p=0.292$). Participation at strenuous sports was significantly associated with age, BMI, and gender. There were significant differences among patients that practiced various categories of sports, in terms of Oxford Hip Score ($p=0.008$), but not in terms of Forgotten Joint Score ($P=0.054$).

Conclusion: 20% of patients practiced strenuous sports regularly or frequently after THA, regardless of pain or discomfort. Participation in sports after THA is strongly correlated with motivation but not with level of discomfort. Longer-term studies with greater focus on complications and survival are necessary to determine whether high-impact sports compromise patient safety or implant longevity.

Figures

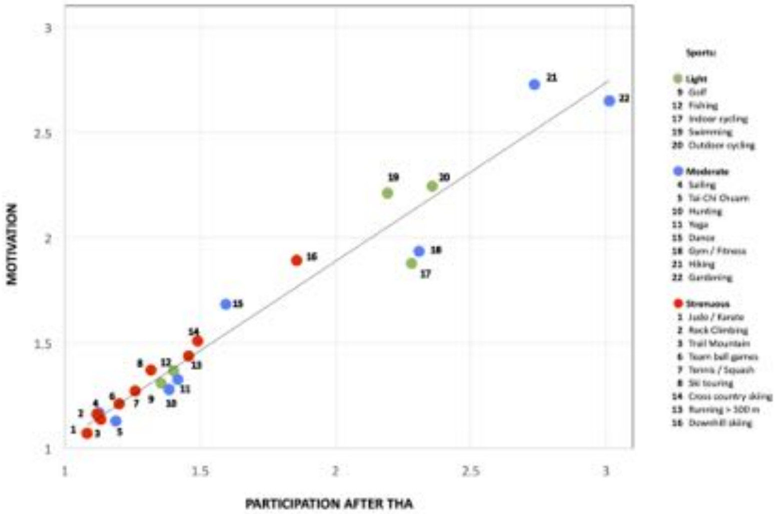
MOTIVATION
PARTICIPATION AFTER THA
Sports:
Light
9 Golf
12 Fishing
17 Indoor cycling
19 Swimming
20 Outdoor cycling
Moderate
4 Sailing
5 Tai-Chi Chuan
10 Hunting
11 Yoga
15 Dance
18 Gym / Fitness
21 Hiking
22 Gardening
Strenuous
1 Judo / Karate
2 Rock Climbing
3 Trail Mountain
6 Team ball games
7 Tennis / Squash
8 Ski touring
14 Cross country skiing
13 Running > 500 m
16 Downhill skiing

Figure 1

#6008

Improved Postoperative Clinical Outcome of Total Hip Arthroplasty Is Related to Patients' Preoperative Expectation

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Introduction

A variety of patient reported outcome (PRO) surveys have been established and validated to evaluate the effectiveness of surgical interventions. The Hip Disability and Osteoarthritis Outcome Score (HOOS) has been validated as one method to evaluate the effectiveness of total hip arthroplasty patients and facilitates the assessment of factors that alter patient outcomes in hip arthroplasty. This retrospective study assesses the effect of psychological post-operative expectations on HOOS in total hip arthroplasty patients. In this pilot study, patient data was collected for 499 patients using the AAOS established Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS) [1] and HOOS surveys.

Method:

Patient data was matched using similar preoperative HOOS scores to allow for comparable room for improvement in HOOS score postoperatively. Patients were placed into groups of high performers and low performers. HOOS is based on a 0 to 100 scale, 100 as the best possible outcome. High performers were defined as those with a HOOS growth ratio of 0.8 and above with the best performers reaching a ratio of 1. Low performers were defined as those with the aforementioned ratio below a value of 0.3. Using these defined groups, we were able to compare the summation of patient specific MODEMS scores using univariate regression. The HOOS growth ratio is calculated based on the following:

HOOS growth ratio = (HOOS postop – HOOS preop)/(100-HOOS preop)

Principal component analysis (PCA) was conducted to identify the significant group of factors that could identify changes in the outcome of 41 patients (20 low performers and 21 high performers).

Results and analysis

PCA was conducted on 5 items with orthogonal rotation (varimax). The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = .0.688, which is well above the acceptable limit of .5 (Field, 2009). Two components had eigenvalues over Kaiser’s criterion of 1 and in combination explained 74.49% of the variance (see Fig. 1). The Scree plot demonstrated the two components that were retained in the final analysis. Component 1 represents expected outcome measured on household activity, sleep comfort, and expected relief; the second component consisted of expected outcome based on recreation activity and expected time to return to job. The outcome of the logistic regression model indicated that the factors in the first component group could significantly identify the performance of patients after surgery.

Conclusions

In this study, we used the MODEMS questionnaire to find the postoperative performance outcome of patients with THA. MODEMS has shown potential in identifying high and low performance individuals; however, the major component in this questionnaire was expected outcome measured on household activity, sleep comfort, and expected relief.

Fig. 1: Scree plot of the eigenvalues for the components.

Figures

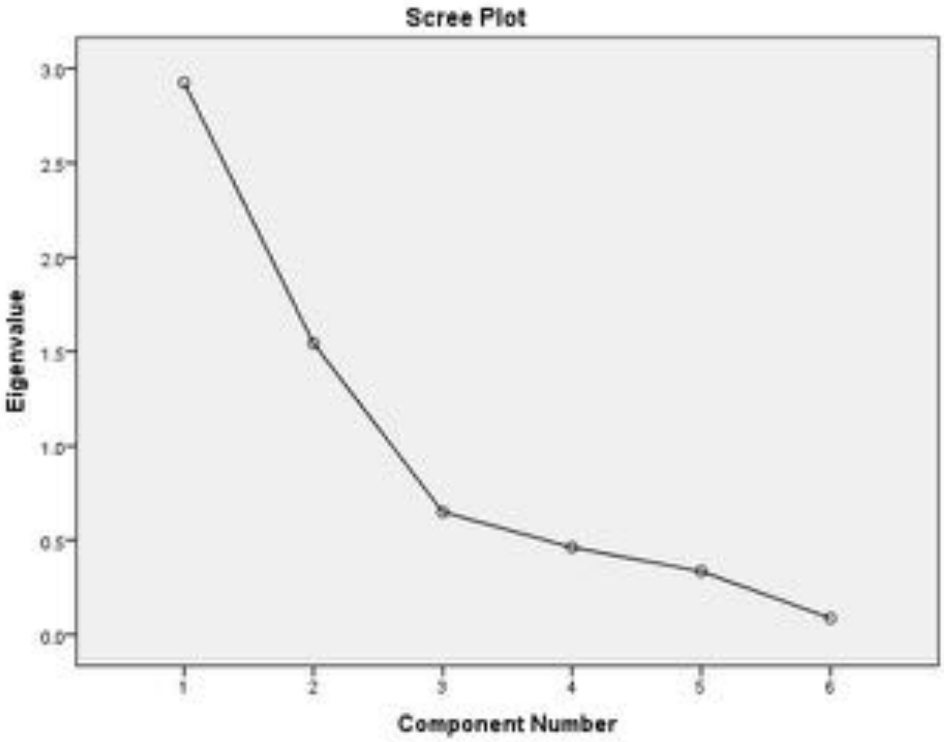

Figure 1

#5780

Does Robotic-Arm Assisted Total Hip Arthroplasty Benefit Short-Term Clinical Outcomes? a Pair Match-Controlled Study.

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Background: Recent advances have made robotic assistance a viable option in total hip arthroplasty (THA). However, in current literature, the clinical outcomes of this procedure relative to manual THA is limited. This study presents short-term outcomes of robotic-arm assisted THA compared to a pair-matched control group of patients that underwent manual THA.

Methods: Data were prospectively collected on all THAs performed from July 2011 to January 2015. Patients were included if they underwent robotic-arm assisted primary THA treating idiopathic osteoarthritis and were eligible for minimum two-year follow-up. Outcomes were measured using Harris Hip Score (HHS), Forgotten Joint Score (FJS-12), pain on a visual analog scale (VAS), and satisfaction from 0-10. Patients that underwent THA with robotic-arm assistance were matched 1:1 with manual THA patients for age, sex, BMI, and approach.

Results: There were 85 patients in each study group. There were no significant differences in the demographic factors matched for. Both HHS and FJS-12 were significantly higher in the robotic assistance group at minimum two-year follow-up (Figure 1). VAS was lower in the robotic assistance group, but this was not statistically significant (p = 0.120). There was no difference in patient satisfaction (Figure 2). There was no significant difference in the rate of complications or subsequent revisions between groups.

Conclusion: Performing THA with robotic-arm assistance may be of benefit to short-term patient outcomes compared to manual THA. There were no differences found regarding the rate of complications or subsequent revisions between groups, suggesting the procedure is safe compare to manual THA.

Keywords: Robotic-arm assisted total hip arthroplasty, clinical outcomes, pair-matched control study, forgotten joint score.

Figures

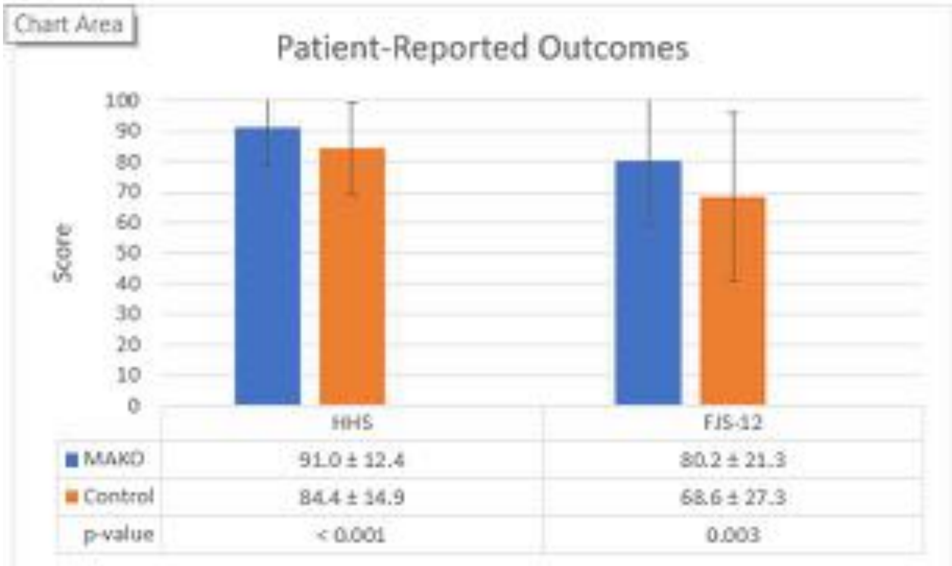

Figure 1

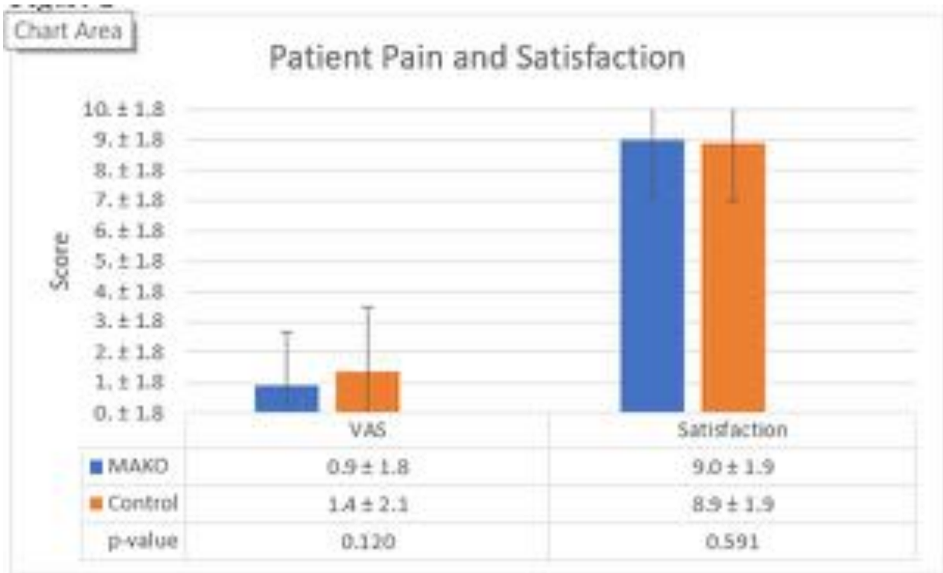

Figure 2

#5903

Dependence of Tibial Post Contact Forces in Posterior Stabilized Total Knee Arthroplasty on Implant Design, Alignment and Activity.

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Posterior stabilized (PS) total knee arthroplasty (TKA), wherein mechanical engagement of the femoral cam and tibial post prevents abnormal anterior sliding of the knee, is a proven surgical technique. However, many patients complain about abnormal clicking sensation, and several reports of severe wear and catastrophic failure of the tibial post have been published. In addition to posterior cam-post engagement during flexion, anterior engagement with femoral intercondylar notch can also occur during extension [1], [2]. The goal of this study was to use dynamic simulations to explore sensitivity of tibial post loading to implant design and alignment, across different activities.

LifeModeler KneeSIM software was used to calculate tibial post contact forces for four contemporary PS implants (Triathlon PS, Stryker; Journey BCS and Legion PS, Smith & Nephew; LPS Flex, Zimmer Biomet). An average model of the knee, including cartilage and soft tissue insertion locations, created from MRI data of 40 knees was used to mount and align the components [3]. The Triathlon femoral component was mounted with posterior and distal condylar tangency at: a) both medial and lateral condylar cartilage (anatomic alignment), b) at the medial condylar cartilage and perpendicular to mechanical axis (mechanical alignment with medial tangency), and c) at lateral condylar cartilage and perpendicular to mechanical axis (mechanical alignment with lateral tangency). The influence of implant design was assessed via simulations for the other implant systems with the femoral components aligned perpendicular to mechanical axis with lateral tangency. Five different activities were simulated.

The anterior contact force was significantly smaller than the posterior contact force, but it varied noticeably with tibial insert slope and implant design (**Fig. 1**). For Triathlon PS, during most activities anatomic alignment of the femoral component resulted in greater anterior contact force compared to mechanical alignment, but absolute magnitude of forces remained small (<100N, **Fig. 2**). Mechanical alignment with medial tangency resulted in greater posterior contact force for deep knee bend and greater anterior force for chair sit activity. For all implants, peak posterior contact forces were greater for activities with greater peak knee flexion (**Fig. 1**). The magnitude of posterior contact forces for the various implants was comparable to other reports in literature [1]. Overall activity type, implant design and slope had greater impact on post loading than alignment method (**Fig 1**).

Tibial insert slope was shown to be important for anterior post loading, but not for posterior post loading. Anatomic alignment could increase post loading with contemporary TKA systems. In the case of the specific design for which effect of alignment was evaluated, the changes in force magnitude with alignment were modest (<200N). Nonetheless, results of this study highlight the importance of evaluating the effect of different alignment approaches on tibial post loading.

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[3] T. Zumbrunn et al., 2016, Knee Surgery, Sport. Traumatol. Arthrosc.

Figures

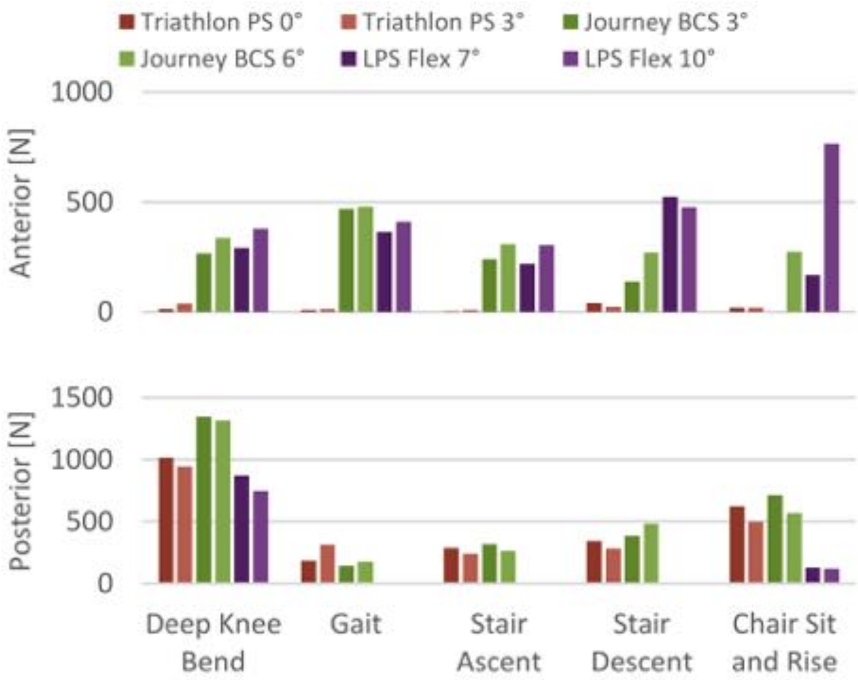

Figure 1: Peak contact forces, acting on the anterior aspect of the tibial post (top) and the posterior (bottom), for the different posterior stabilized implant systems with the tibial insert at the recommended and additional 3° posterior slope (noted) and the femoral component in mechanical alignment with distal and posterior tangency at the lateral condylar cartilage.

Figure 1

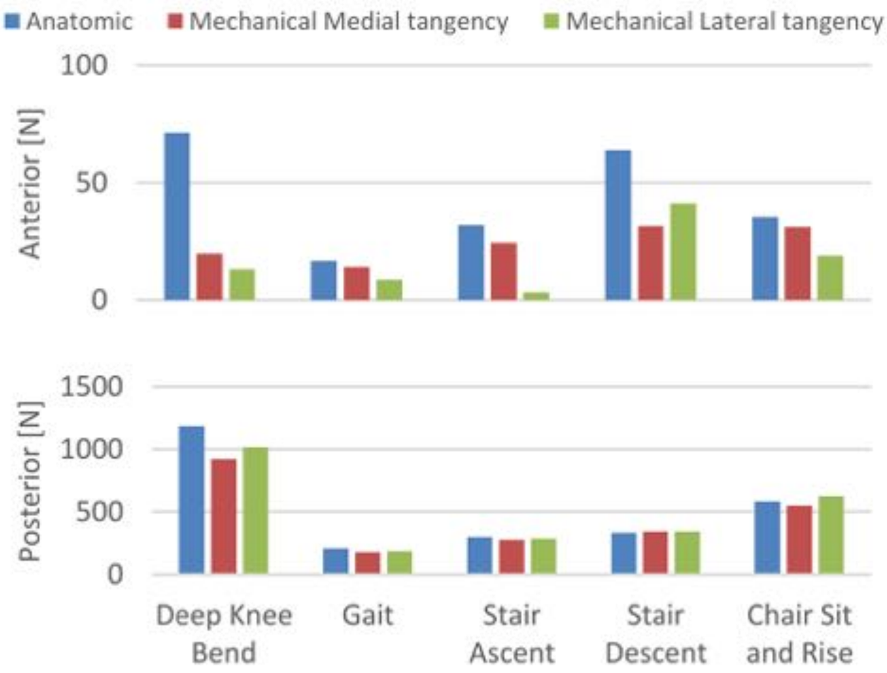

Figure 2: Peak contact forces, acting on the anterior aspect of the tibial post (top) and the posterior (bottom), for Stryker Triathlon posterior stabilized implant with the tibial insert at 0° posterior slope and the femoral component aligned using the three different methods.

Figure 2

#5673

Mechanical Properties of the Knee Envelope Are Different in Flexion and Extension: Measurements During TKA

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Introduction

In order to achieve good clinical results in TKA, soft tissue balance is important. Soft tissue balance is closely related to knee kinematics which affects clinical results. Modified gap balancing technique is one of the standard techniques for posterior stabilized (PS) TKA. On the other hand, appropriate load for obtaining gap balance has not been established.

We have reported preliminary results of mechanical properties that load deformation curves of knee sleeve structures showed bimodal patterns with toe region and linear regions with using newly developed ligament balancer. The purpose of the present study is to measure the mechanical properties of soft tissue structure of knee sleeve in flexion and extension during PS TKA. The understanding of the mechanical properties is crucial. In particular if these properties are used as input for surgical procedures, standard technique for many surgeons will be established.

Materials and Methods

Medial compartmental osteoarthrosis (OA) patients (25 female and 15 male) were evaluated. Average age, BMI, and Varus deformity were 73.1+/-9.4 years, 26.7+/-5.1, and 13+/-6.5 degrees, respectively. Load deformation curves were obtained after distal femoral cut and proximal tibial cut with the knee in extension and flexion in 90 degrees.

We obtained a transitional load that switching over from toe region to linear region with linear regression analysis of each region. Stiffness was also obtained from the load deformation curves.

Results

Mechanical properties of the knee envelope are different in flexion and extension position. Transitional loads were 160+/-12 N in extension (Fig. 1), and 140+/-10N in flexion (Fig. 2). Stiffness in extension and flexion were 14.4 N/mm and 20 N/mm, respectively.

Discussion

In the past reports, many authors have claimed ligament balance technique with operators’ experience. Some of the authors explain the appropriate ligament balance as the “steel rod test” or “palpable endpoint”. If quantitative methods to achieve good flexion and extension balance is established, that will enable low volume surgeon to obtain good clinical results after TKA.

It has been reported that a load on ligament is below the transition zone during 80% of normal daily activity. The present results of load deformation curves of soft tissue structure of knee sleeve showed bimodal patterns with toe region and linear regions same as the ligaments and tendons. These results indicated that the so called “palpable endpoint” may be transitional load. Ritschl P et. al. named this load as stability range

(CAOS 2006).

According to the present data, we will propose a standard modified gap balance technique in PS TKA for medial compartmental osteoarthrosis. The ligament balance is confirmed in extension with 160N of distracting force after soft tissue release and distal femur and proximal tibial cut. The femoral component rotation is then decided with the 140N of load that will open the distance to the thickness of the tibial component in flexion.

Figures

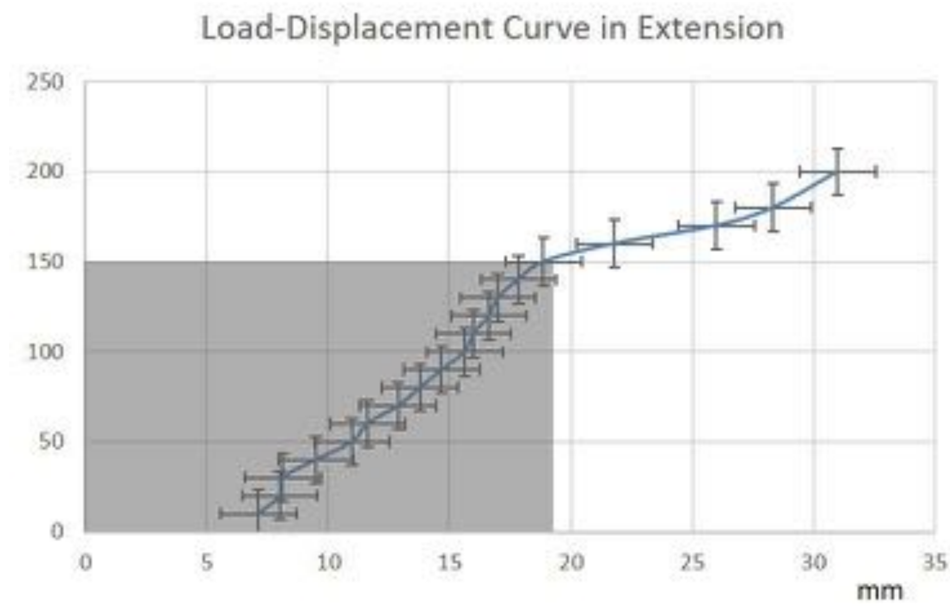

Figure 1

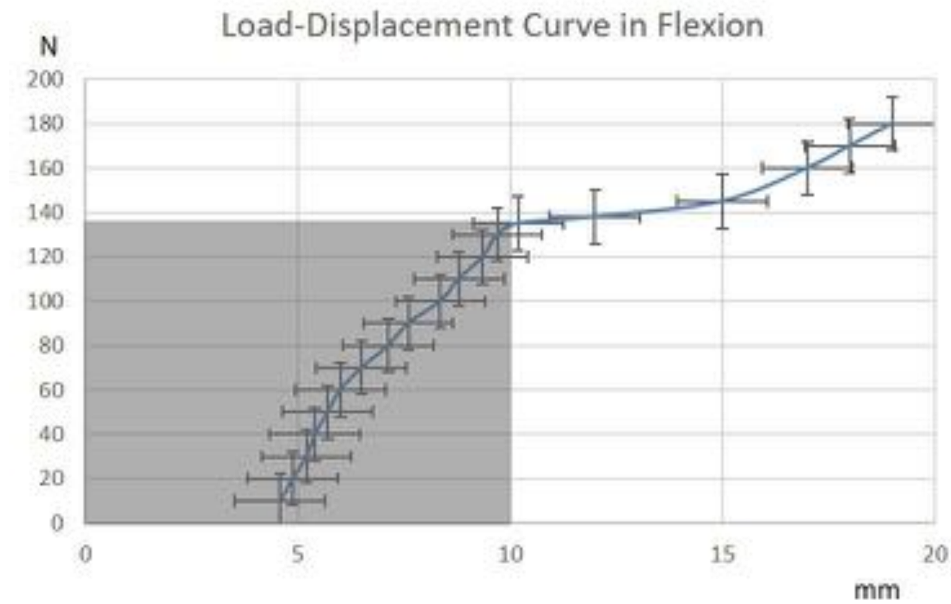

Figure 2

#5791

Utilization of Mathematical Model to Assess Various TKA Designs and Component Positioning

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Introduction:

Forward solution modeling (FSM) is a powerful tool for fast and cost-efficient simulation of in vivo mechanics used in quantifying outcomes of knee implant design and implantation. Unlike most evaluation strategies, mathematical molding allows for testing new implant designs before manufacturing and implantation, providing early insight into follow-up outcomes used to better assess potential success. The proposed knee FSM is capable of analyzing existing commercial TKA and novel implant designs. This FSM has been developed to include different activities including deep flexion, extension, and gait providing component placement options in virtual surgery. The objective of this study was to use the knee FSM to assess different implant designs, surgical techniques under various weight-bearing activities to assess the viability of predicting postoperative outcomes before initial implantation into patients.

Method:

Due to the mechanical complexity human body, the knee joint is modeled computationally through equations of motions derived using of Kane's system of dynamics. The dynamic model is driven by muscle forces applied using a controller and constrained by soft tissue properties and contact detection algorithms allowing for contact mechanics to be obtained. The model is parameterized with inputs including CAD geometries, material properties and transformation definitions (Figure 1). Implant geometries are transcribed into mathematical representations, determining contact at desired regions of the tibiofemoral and patellofemoral joints. In addition to joint contact, the cam/post interaction is also assessed in posterior stabilized (PS) TKA. Therefore, the model can assess posterior cruciate retaining (PCR) TKA, PS TKA and both fixed and mobile bearing designs. Components are oriented with respect to the bones in a manner similar to surgery, allowing for evaluation of implant conditions and dynamics. Through virtual surgery, the effects of different surgical techniques on the outcome of the TKA can be assessed. Using the model, several scenarios were modeled to assess varying implant types, surgical conditions, and activities to understand the effect of each on knee kinematics.

Results:

The FSM model has been validated to predict maximum knee forces within 4% of known telemetry implant forces (Figure 2) and within 1 mm and 1 degree of rotation compared to fluoroscopy (Figure 3). The results of posterior-stabilized implant reveal cam/post forces increasing linearly with knee flexion. Furthermore, the model demonstrates differences between implant types, optimizing device selection by a physician on a case by case basis. Placement of the components in varus and valgus can also lead to an additional 0.5 times bodyweight of medial and lateral compartment forces. The model also revealed that the implant forces and kinematics are quite different than a normal knee and various implants and implantation of the components could increase the knee forces by 1.0 times bodyweight and lead to abnormal knee kinematics as seen previously with fluoroscopy.

Conclusion:

Evaluating existing implant designs with the FSM indicates similar findings with fluoroscopic data. Various implant design and implanted conditions were evaluated assessing predictive postoperative outcomes. The model revealed distinct differences when components were mal-rotated or mal-aligned and PS TKA designs achieve more rollback than PCR TKA designs.

Figures

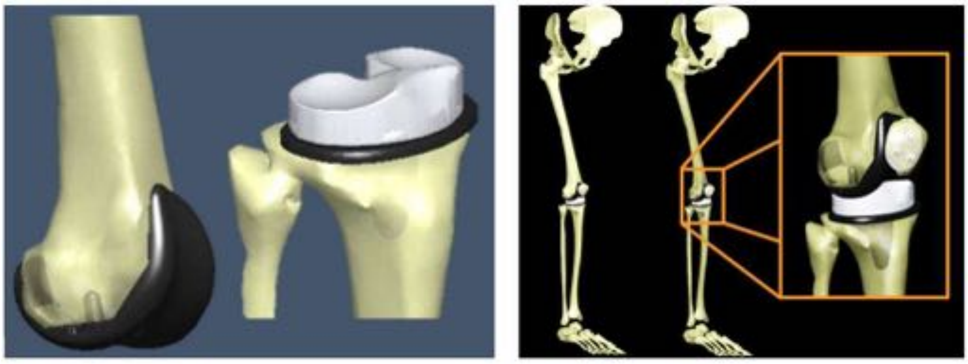

Figure 1:Parametrizing the FSM with CAD models of implant components.

Figure 1

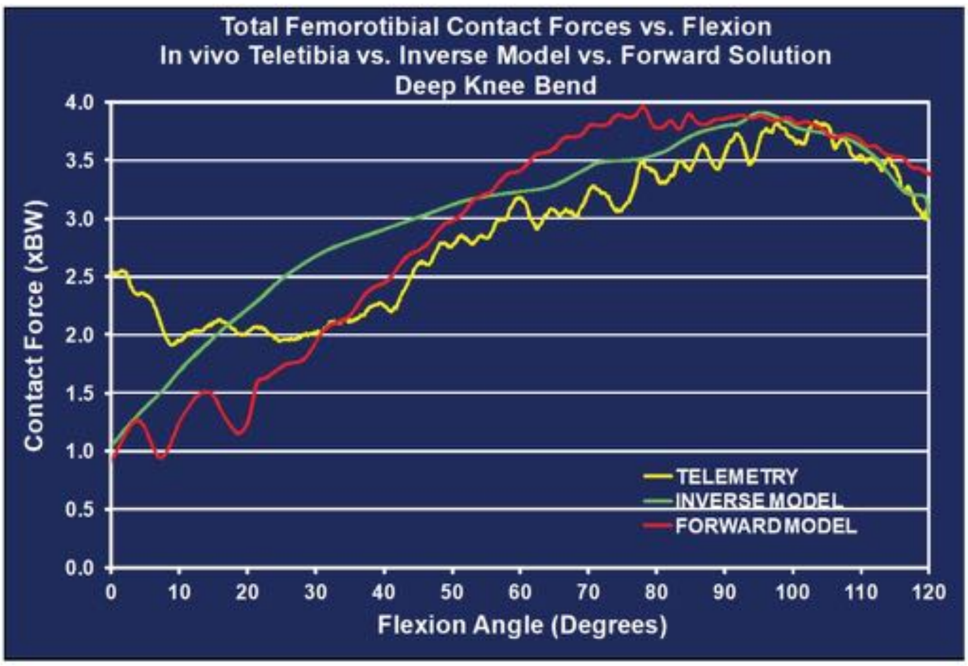

Figure 2: The FSM validation with telemetry data.

Figure 2

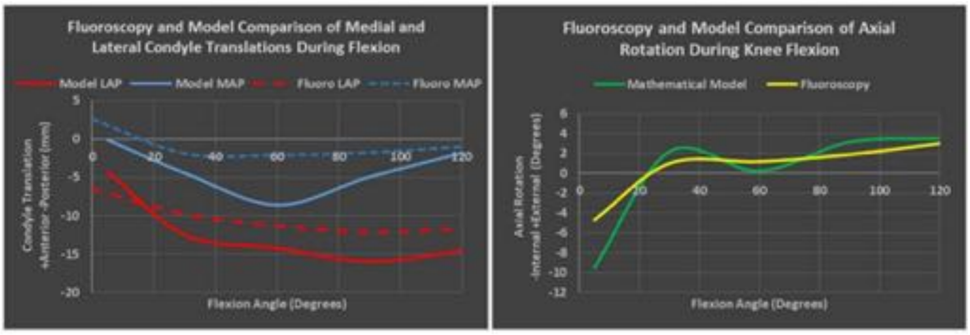

Figure 3: FSM validation with fluoroscopy data.

[Figure 3]()

#5959

Knee Ligament Recruitment Probability Under Distraction Loading

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Introduction

Knee ligaments guide and restrain joint motion, and their recruitment during passive motions is an area of focus during total knee arthroplasty. During gap balancing distraction forces may be applied using an intra-operative instrument, which tensions the ligaments and indirectly informs tissue releases. These mechanical distraction devices have been used with surgical navigation to provide intraoperative measures of distraction loads and corresponding kinematics[1]. Such intraoperative data could be used with patient-specific geometry to estimate ligament lengths throughout a range of motion, where the information could also be used to target specific ligaments during the balancing procedure. The purpose of this study was to evaluate ligament length changes during surgically relevant joint distraction tests across a range of flexion angles.

Methods

One knee specimen was prepared following the OpenKnee(s)[2] experimental protocol. In short, registration markers along with femoral and tibial landmarks were digitized to define a clinically relevant coordinate system[3], and the specimen was MR imaged. After imaging an orthopedic surgeon removed the skin, muscle, meniscus, patella, and femoral articulating surfaces. A six degree-of-freedom robot (SimVitro, Cleveland Clinic) performed three distraction tests at 0^o , 30^o , 60^o , and 90^o flexion. The first test increased joint distraction from 25 N to 100 N. The other two tests applied the same distraction loading while the varus or valgus angle was fixed at 5^o . Joint kinematics were measured throughout.

Specimen specific ligament geometry was defined from the MR images (Figure 1). Femoral and tibial surfaces were segmented, and ligaments were defined by manually placing four points at the margins of the femoral and tibial insertion sites (Figure 1). A total of 11 ligament bundles were defined (Figure 1). The experimental kinematics were used to calculate ligament length throughout each test. Wrapping was approximated around the femoral surface and the medial tibial plateau. Ligament recruitment ”probability”[4] at the peak load of every test was calculated from ligament lengths.

Results and Discussion

The average recruitment probability of the cruciates was highest at 90^o flexion for every distraction test (Figure 2). This behavior is similar to previous clinical studies, which have shown that PCL resection significantly increases the flexion gap, but not the extension gap[5]. The superficial MCL had the highest average recruitment probability for the fixed valgus distraction test at 0^o flexion. The lateral collateral ligaments (LCL, ALL, PFL) had the highest average recruitment probability during the fixed varus tests, and lower recruitment probability during the fixed valgus tests (Figure 2). Similar methods will be applied to additional specimens for both validation as well as to assess factors that indicate the need for patient-specific analysis. This study demonstrates how imaging, novel distraction loading, and kinematics can be used to calculate the probability of ligament recruitment. This information could help inform the joint balancing process by highlighting the tissues that contribute to patient-specific joint response.

References

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Figures

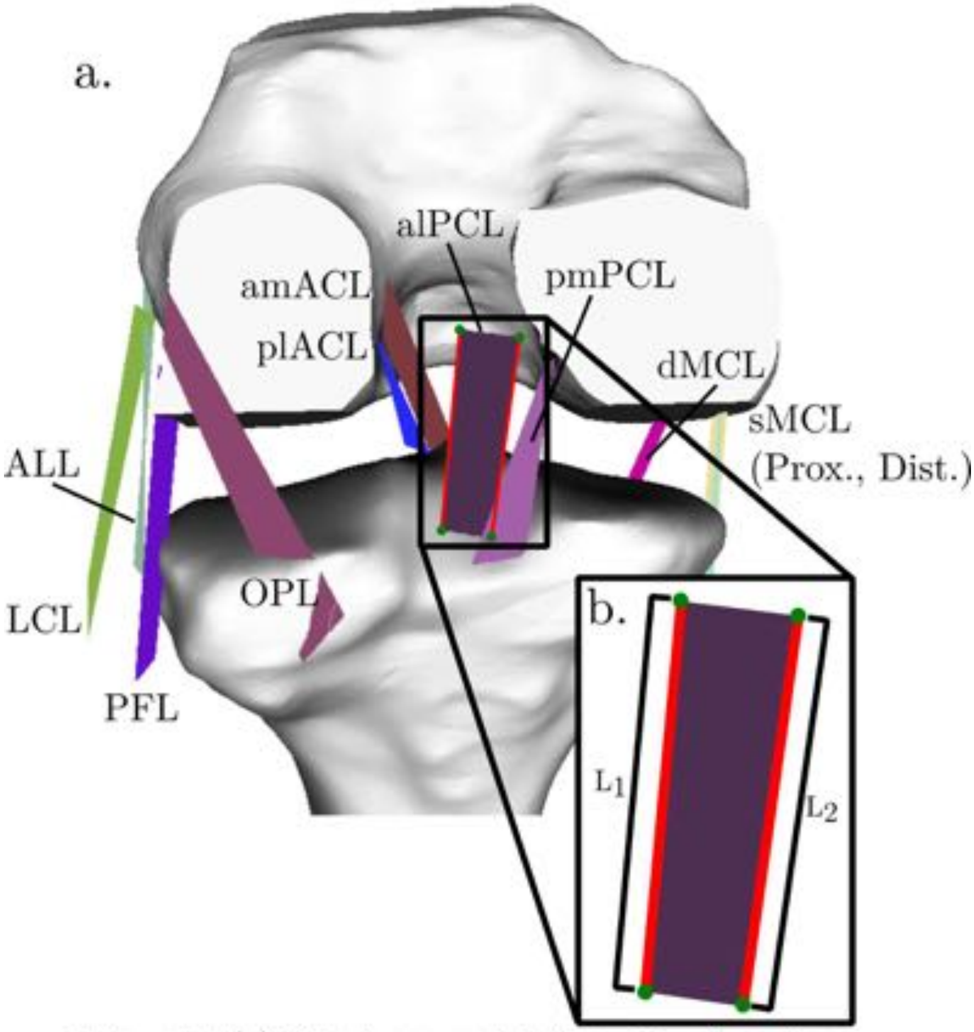

Figure 1: (a) The knee model that visualizes the surgical cuts and the 11 ligament bundles that were modeled. Note that ligament wrapping is not shown. (b) An example of the two length measurements for the alPCL.

Figure 1

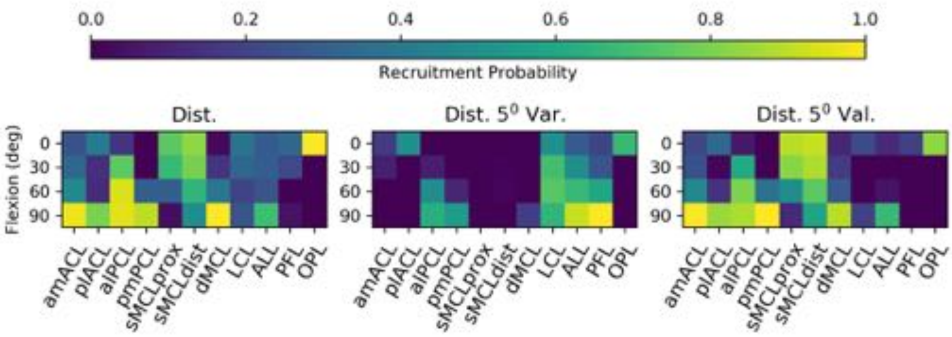

Figure 2: Recruitment probability for the (left) distraction test, (middle) distraction test with 5° varus, and (right) distraction with 5° valgus for 0°, 30°, 60°, and 90° flexion. Note that a probability of 1.0 indicates maximal recruitment of both fibers that defined a ligament bundle.

Figure 2

#5751

The Effects of Posterior Tibial Slope, Loading Distribution and Flexion Angle on Anterior-Posterior Constraint of Total Knee Replacements

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Introduction

Pre-clinical assessment of total knee replacements (TKR) can provide useful information about the constraint provided by an implant, and therefore help the surgeon decide the most appropriate configurations. For example, increasing the posterior tibial slope is believed to delay impingement in deep flexion and thus increase the maximal flexion angle of the knee, however it is unclear what effect this has on anterior-posterior (AP) constraint.

The current ASTM standard (F1223) for determining constraint gives little guidance on important factors such as medial-lateral (M:L) loading distribution, flexion angle or coupled secondary motions. Therefore, the aim of the study was to assess the sensitivity of the ASTM standard to these variations, and investigate how increasing the posterior tibial slope affects TKR constraint.

Methods

Using a six degree of freedom testing rig, a cruciate-retaining TKR (Legion; Smith & Nephew) was tested for AP translational constraint. In both anterior and posterior directions, the tibial component was displaced until a ‘dislocation limit’ was reached (fig. 1), the point at which the force-displacement graph started to plateau (fig. 2). Compressive joint loads from 710 to 2000 N, and a range of medial-lateral (M:L) load distributions, from 70:30% to 30:70% M:L, were applied at different flexion angles with secondary motions unconstrained. The posterior slope of the tibial component was varied at 0°, 3°, 6° and 9°.

Results

AP translation was significantly larger at 60° and 90° flexion (22 ± 1 mm and 24 ± 1 mm respectively) than at 0° (14 ± 1 mm), whilst increasing the compressive joint load increased the force required to translate the tibia to limits of AP constraint at all flexion angles tested. When the M:L load distribution was shifted medially, a coupled internal rotation was observed with anterior translation and external rotation with posterior translation; this was reversed with a lateral shift in load distribution.

It was also found that increasing the posterior slope of the tibial tray moved the neutral position of the tibia relative to the femur more anteriorly at all flexion angles tested. The constraint under anterior drawer was then reduced with increasing slope, which meant that the tray dislocated at lower drawer force and translations.

Conclusions

When intraoperative tibial bone cuts are made, surgeons should be aware that by increasing posterior slope angles the TKR may offer less anterior constraint under body-weight loads, therefore relying more heavily on surrounding soft-tissue and muscle action to prevent dislocation.

The ASTM test protocol could be refined to stipulate the variation of the M:L loading distribution. It has been shown to vary between patients and activities, and the AP constraint and associated secondary motions in this study were very sensitive to this distribution. The secondary motions observed should be measured and recorded to provide more information about the device's stability characteristics. The tests could also be extended to include a higher axial load such as 2000 N, approximately three times body weight, in order to investigate coupled rotations and M:L distribution effects whilst under normal walking gait loads.

Figures

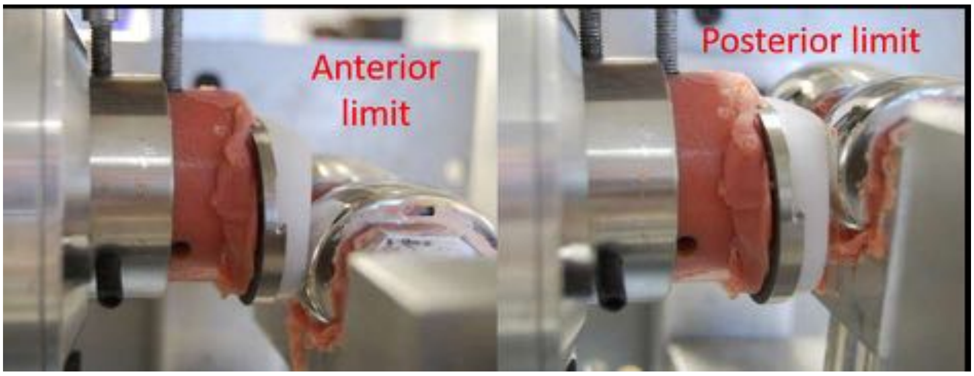

Figure 1

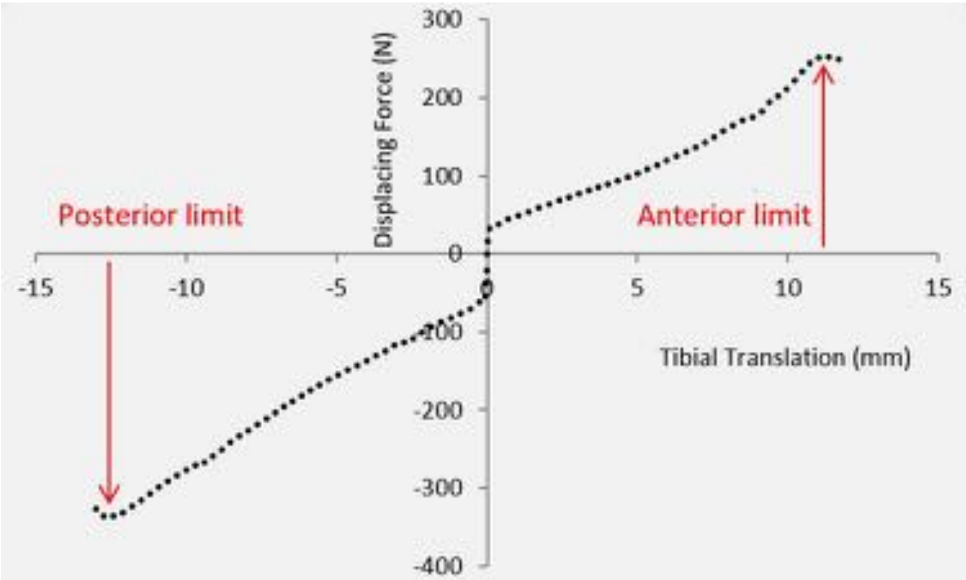

Figure 2

#5575

Compromise in Component Placement: A Comparison Between Symmetric and Anatomic Patellar Designs

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INTRODUCTION

Patellofemoral complications are among the most common causes of complaints and revisions following total knee arthroplasty (TKA). Considerations during patellar resurfacing include patellofemoral tracking, composite thickness, bony coverage, and component overhang. The patellar composite should have the thickness equivalent to that of the native bone to avoid disruption of the extensor mechanism; and good bony coverage facilitates better load transfer, avoids soft tissue impingement and lateral facet syndrome. However, with symmetric patellar design, a surgeon may need to compromise composite thickness and coverage to avoid component overhang. Asymmetric patellar designs may offer improved component fit with less compromises. This study compared the incidence and degree of compromises between a symmetric design and an anatomic design.

MATERIALS AND METHODS

A surgeon validated computational algorithm virtually resurfaced 100 CT based patellar models (50 Asian: 25M/25F; 50 Caucasian: 25M/25F) with a symmetric design and an anatomic design (Fig 1). First, a series of design-specific patellar resections were automatically created by removing the exact thickness corresponding to each component size. In the cases that the remaining bone thickness was less than 12mm, the resection maintained the 12mm bone stock. The proper resection level and its corresponding “ideal” component size was then determined on each patella for each design. During component placement, the “ideal” sized component for each design was first placed on the patellar resection. If more than 1mm overhang was observed, the next smaller component size will be used for the placement. This process was repeated until overhang was under 1mm. The incidence and degree of downsizing, as well as compromise in bony coverage and thickness due to downsizing were compared between the two designs. Significance was defined as $p<0.05$.

RESULTS

Compared to the symmetric patellar design, the anatomic design exhibited better component fit with lower incidence and degree of downsizing (Table 1 and Fig 2). Ideal sizes of the anatomic design were implanted in 84% of the bones, avoiding the compromises in coverage and thickness. In contrast, only 37% of the bones were implanted with the ideal sizes for the symmetric design. Most of the downsizing cases in the anatomic design (12 out of the 16 downsized) required just 1 size smaller than the ideal size, while for the symmetric design, a fair amount of cases required 2 sizes (23/63) or even 3 sizes (3/63) smaller. Even with downsizing, the coverage in the downsized anatomic design group was significantly higher compared to the symmetric design group (Table 1).

DISCUSSION

Compared to the symmetric patellar design, the anatomic design significantly lowered the incidence and degree of compromises in composite thickness and bone coverage due to downsizing the component. Even in the downsized group, the coverage of the anatomic design was higher than the pooled average in symmetric design. The results demonstrated that the anatomic patellar design greatly improved the component fit than the traditional symmetric design. This computational study provided a standardized workflow for the investigation of patellar component fit, and may be applied to compare across additional designs.

Figures

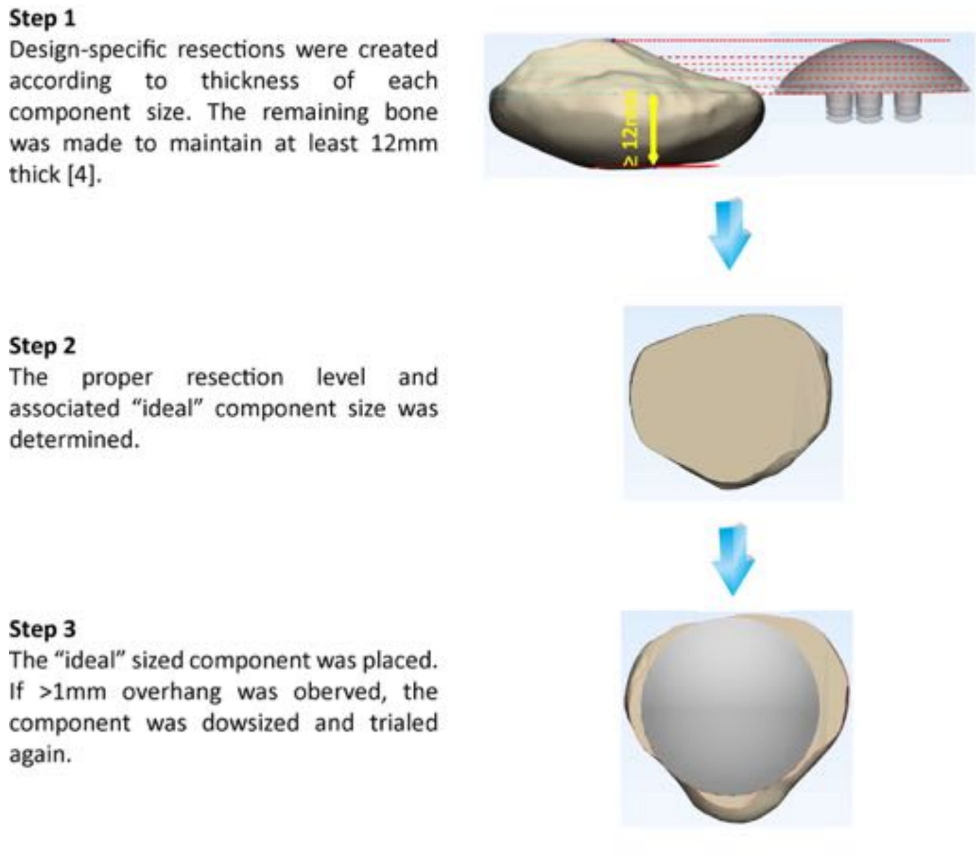

Figure 1. Computational workflow.
Figure 1

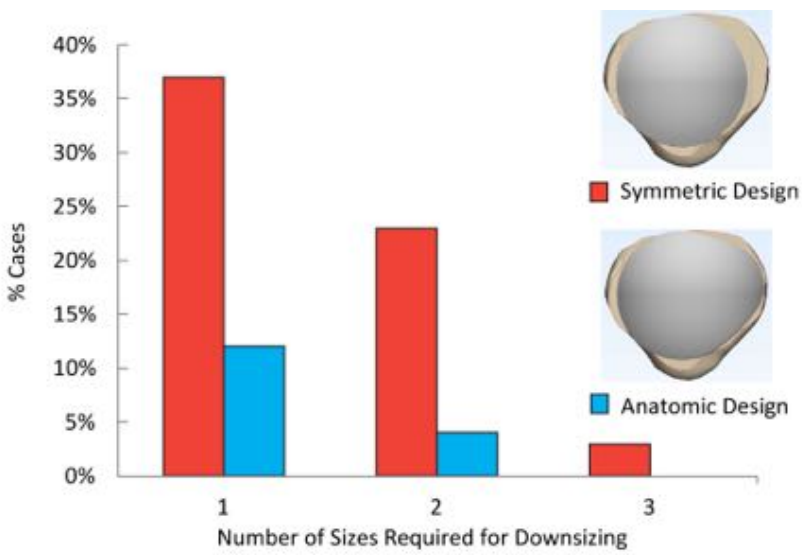

Figure 2. Summary of component downsizing for the symmetric and anatomic designs.
Figure 2

	%Cases Downsized	Bony Coverage (%)	Thickness difference (mm)*
Pooled			
Symmetric Design	-	80.5 ± 5.6	1.4 ± 1.2
Anatomic Design	-	84.1 ± 6.2	0.6 ± 1.2
P		0.000	0.000
Downsized Cases			
Symmetric Design	63%	80.0 ± 5.7	2.1 ± 0.9
Anatomic Design	16%	83.1 ± 4.6	2.4 ± 1.0
P	0.000	0.048	0.238

* Positive value indicates that the native patella is thicker than the implanted patella.

Table 1. Summary of %case downsized, coverage and thickness difference in the symmetric and anatomic designs. Significance was defined as $p<0.05$.

Figure 3

#5776

Prevention and Treatment of Osteomyelitis Following Open Fractures by Use of a Medicated Bone Graft Substitute in a Developing Country Setting.

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Introduction

Today, Uganda has the second highest rate of road accidents in Africa and the world after Ethiopia. According to the World Health Organization's Global Status Report on Road Safety 2013, Uganda is named among countries with alarmingly high road accident rates. If such trend of traffic accidents continues to increase, the health losses from traffic injuries may be ranked as the second to HIV/AIDS by 2020. These road traffic accidents often result in terrible open injuries. Open fractures are complex injuries of bone and soft tissue. They are orthopedic emergencies due to risk of infection secondary to contamination and compromised soft tissues and sometimes vascular supply and associated healing problems. Any wound occurring on the same limb should be suspected as result of open fracture until proven otherwise. The principles of management of open fracture are initial evaluation and exclusion of life threatening injuries, prevention of infection, healing of fracture and restoration of function to injured extremity. Because of the poor hygienic circumstances and the high rate of cross-infection due to the crowded patient-wards, the risk of getting a post-operative infection is relatively high.

Osteoset-T® (Wright Medical) is a medical grade calcium sulfate bone graft substitute which is enhanced for use in infected sites by incorporating 4% tobramycin sulfate.The tobramycin is released locally, allowing therapeutic antibiotic levels at the graft site, while maintaining low systemic antibiotic levels. This local treatment of infection allows new bone formation in the defect site, while decreasing potential systemic effects.

Purpose/aim

Prevention and treatment of postoperative osteomyelitis by introducing alcoholic hand-sanitizers and the use of wound debridement and implantation of a medicated bone graft substitute.

Materials and Methods

We treated some existing osteomyelitis cases and some open fractures with the medicated bone graft substitutes, at Kilembe Mines Hospital, Uganda. A proper debridement with sequestrectomy when needed was performed after which the pellets were implanted and the wound was closed. A preoperative X-ray was taken as well as clinical pictures. Post-operative x-rays were obtained at 6 weeks post-operative and 6 months post-operative when possible. The case presented in this abstract is a 25year old nurse with a bilateral open tibia fracture due to a motorcycle accident. A proper debridement and plate and screw osteosynthesis was performed after which the pellets were implanted underneath the plate. After surgery systemic antibiotics were given and the wound-dressings were changed when dirty.

Results

The case presented is currently 6 months post-operatively and is able to walk without support. The fracture is fully consolidated and the wounds are healed without any sign of infection.

Conclusion

Even though the clinical follow-up is not easy in this developing country setting, we were able to evaluate some patients postoperatively. By introducing better hand hygiene (by use of alcoholic hand sanitizers) and medicated bone graft substitutes, we hope to be able to prevent osteomyelitis after open fractures and also to treat chronic osteomyelitis cases. More people are being treated at the moment and a case-control study will be started soon.

#6019

Patient Reported Outcomes After Total Hip Arthroplasty in a Developing Country by a Visiting Surgical Team: A 1-Year Update

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Background:

Total hip arthroplasty (THA) is a highly successful procedure, yet access to arthroplasty is limited in many developing nations. In response, organizations around the world have conducted service trips to provide international arthroplasty care to underserved populations. Little outcomes data are currently available related to these trips. We present a 1-year follow up.

Methods:

We completed an arthroplasty service trip to Brazil in 2017 where we performed 46 THAs on 38 patients. Patient demographic data, comorbidity profile, complication data, and pre- and postoperative Modified Harris Hip Score (mHHS), PROMIS Short Form Pain (SF-Pain), PROMIS Short Form Physical Function (SF-Function), and HOOS Jr scores were collected. Outcomes were collected postoperatively at 2, 6, and 12 weeks and 1 year. A multivariate regression analysis was performed to identify associations between patient factors and 12-week outcomes.

Results:

The mean patient age was 48.8 years. 47% were female. 30 patients had a unilateral THA and 8 had bilateral simultaneous THA (table 1). 61% of patients had a preoperative diagnosis of osteoarthritis (OA), 13% avascular necrosis, 13% post-traumatic OA, 8% developmental hip dysplasia, and 5% rheumatoid arthritis. Mean pain duration was 1-5 years for 45% of patients and >5 years for 55% of patients.

The mean mHHS, HOOS, PROMIS SF-Pain and PROMIS SF-Function all improved significantly compared to baseline at 2, 6, 12 weeks and 1 year post-operatively (table 2, figure 1 & 2).At 1 year, only 11 of 38 patients (29%) were reachable by phone for follow up. The mobile phones were out of service for 27 of 38 patients (71%).

Multivariate regression analysis did not reveal any associations at 12 weeks between patient reported outcomes and age, gender, pain duration, preoperative diagnosis or unilateral versus bilateral surgery (table 3).

Conclusion:

We found that patients in a developing country benefitted significantly from THA when performed by a visiting surgical team. Outcomes were similar to those seen in the United States. Of those that could be contacted, outcomes were stable at 1 year. This

study highlights the difficulty of following patients in developing countries once they leave the hospital. Methods need to be developed to assure that the outcomes of these potentially valuable procedures can be determined. We are currently establishing the capability of using email and smart phone applications linked through email addresses to improve follow up on future missions.

Figures

Table 2: Patient Reported Outcomes - Summary

	Pre-operative		2 week		6 week		12 week		1 year	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Modified Harris Hip Score	28.5	13.9	54.7	18.5	69.1	12.6	88.0	5.4	92.5	15.9
HOOS Jr.	29.8	18.4	66.5	14.2	82.0	15.3	99.0	4.8	94.7	10.5
PROMIS SF Pain Interference	53.9	7.9	71.0	6.8	75.5	4.5	76.9	3.9	76.6	5.5
PROMIS SF Physical Function	27.7	5.3	35.4	7.1	43.0	8.1	50.6	7.9	53.5	9.5

Figure 1

Table 3: 12 Week Logistic regression analysis

	Modified Harris Hip Score		HOOS Jr.		PROMIS SF Pain Interference		PROMIS SF Physical Function	
	Mean	p-value	Mean	p-value	Mean	p-value	Mean	p-value
Gender:								
Male	51.5	0.24	**57.3**	**0.003**	18.0	0.26	21.3	0.30
Female	59.8		**81.8**		24.9		24.4	
Age *	p = 0.34, r-square = 0.05		p = 0.35, r-square 0.03		p = 0.67, r-square = 0.007		p = 0.22, r-square = 0.06	
Pain duration:								
Pain for 1-5 years	53.2	0.48	72.8	0.72	23.3	0.46	22.6	0.29
Pain for > 5 years	58.0		68.4		20.3		23.3	
Preoperative diagnosis:								
OA	59.5	0.46	72.5	0.53	23.7	0.49	26.0	0.18
AVN	54.8	0.93	57.7	0.70	13.7	0.11	23.0	0.23
DDH	50.5	0.56	73.5	0.85	18.4	0.42	14.1	0.17
Posttraumatic	55.1	0.94	69.3	0.51	15.6	0.26	12.9	0.07
RA	58.2	0.75	83.4	0.27	**37.3**	**0.008**	26.9	0.25
Unilateral vs. Bilateral:								
Unilateral THA	50.9	0.24	72.0	0.46	23.1	0.15	22.6	0.75
Bilateral simultaneous	60.3		65.2		16.7		24.5	

* Bivariate analysis

Figure 2

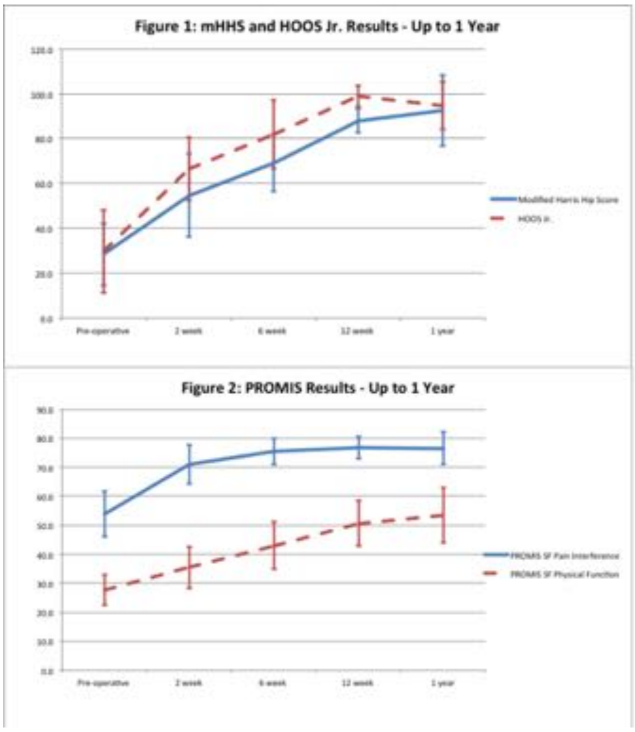

Figure 1: mHHS and HOOS Jr. Results - Up to 1 Year
Figure 2: PROMIS Results - Up to 1 Year

[Figure 3](#)

#5594

Video Fluoroscopy-Based Evaluation of the Error of Skin-Marker-Based Motion Capture in the Retrieval of Hip Joint Center Location and of Hip Rotations During Four Activities of Daily Living.

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Title

Video fluoroscopy-based evaluation of the error of skin-marker-based motion capture in the retrieval of hip joint center location and of hip rotations during four activities of daily living.

Introduction

Accurate knowledge of the patient-specific kinematics of the prosthetic hip joint during activities of daily living is important to evaluate implant performance [1]. Kinematics retrieved with conventional motion capture methods are affected by soft tissue artifacts (STA). Recently, the effect of STA on predicted hip joint kinematics was evaluated during treadmill walking using video-fluoroscopy as reference [2]. However, no study has evaluated yet STA for a broader range of realistic motion activities, i.e. free gait, stair descent, chair rise and putting on socks. The aims of this study were to quantify the error induced by STA on the hip joint kinematics during these dynamic activities, and to evaluate the dependence of the error on the joint segment and on the activity.

Methods

Four activities of daily living (gait, stair descent, chair rise, putting on socks) were measured simultaneously with optical motion capture (MC) at 100 Hz and with a movable single-plane video-fluoroscopy system (VF) at 25 Hz, for four patients with successful total hip arthroplasty (THA). The joint segment positions were computed by least-square fitting for MC and by manual 2D/3D registration for VF. Anatomical coordinate systems were defined for each joint segment based on skin markers location at a reference standing position. Errors induced by STA on the retrieved joint motion were computed as the absolute difference (AE) between MC and the reference VF.

Results

MC underestimated the ROM of flexion and ROM of adduction of the hip joint in all activities: the mean errors were 5.1° and 3.4° for gait, 6.2° and 6.7° for stairs descent, respectively (Figure 1). Flexion angle was underestimated by MC during phases of each activity with higher degree of hip flexion (Figure 2). Internal rotation of the hip was overestimated by MC throughout the whole cycle of each activity (AE = 4.6°±3.0° for gait, 5.6°±4.7° for stairs descent, 8.7° for chair rise, 11.3±7.6° for putting on socks). MC error for the thigh was larger than the MC error for the pelvis. MC errors above 1 cm were observed for the location of the hip joint center, with higher values for the cranial-caudal direction (Figure 3).

Discussion

STA led to an underestimation of the ROM of the skin markers segments with respect to the underlying joint segments, and to an overestimation of the internal rotation of the hip joint. STA affected more the thigh than the pelvis, possibly due to larger amount of soft tissue, hence of skin deformation, for the thigh. This study lays the basis for activity-dependent corrections of STA for each segment of the hip joint. Findings of this study will be finalized with the measurements of 15 THA subjects.

Acknowledgments

Funding: EU FP7-NMP-2012-LARGE-6, Grant 310477 (“LifeLong-Joints”)

References

1. Mellon, S.J., et al., (2013). *Proc Inst Mech Eng H* 227(7):799-810

2. Fiorentino, N.M., et al., (2017). *Gait & Posture* (55):184-190

Figures

ROM	Gait		Stairs descent		Char rise		Putting socks on	
	MC	VF	MC	VF	MC	VF	MC	VF
Flexion [°]	38.3±4.9	43.4±5.3	22.5±3.0	28.7±2.4	83.6	98.2	115 (max)	106 (max)
Adduction [°]	9.9±2.0	13.3±0.8	10.7±2.8	17.4±2.9	6.4	12.3	24	11
Int.Rot. [°]	13.4±3.5	14.3±3.8	16.6±2.0	14.8±2.7	9.3	14.6	34	18

Figure 1: Comparison between MC and VF of ROM of hip rotations (mean ± std) for 4 activities of daily living. Yellow fields show statistically significant difference between MC and VF (not tested for Chair Rise and Putting on socks).

Figure 1

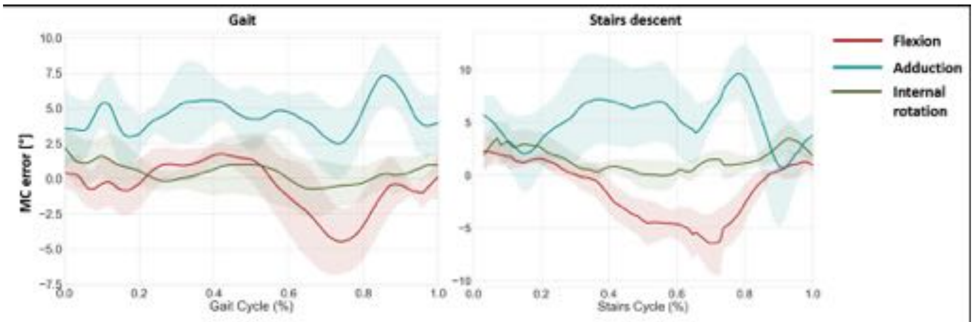

Figure 2: MC error curves (mean and standard deviation) for hip rotations over normalized cycle, for 4 THA patients (5 cycles per patient).

Figure 2

	Gait		Stairs descent		Socks on		Chair rise
Medial-lateral	12.2	±8.4	12.0	±7.9	16.2	±11.4	14.0
Anterior-posterior	11.2	±8.8	12.5	±8.2	16.6	±14.3	8.7
Cranial-Caudal	18.1	±7.4	16.0	±8.5	8.1	±5.7	8.7

Figure 3: MC absolute error [mm] in estimation of Hip Joint Center location along anatomical axes, for 4 activities of daily living.

Figure 3

#5982

Femoral Neck Cut Anteversion Predicts Stem Anteversion in Cementless Total Hip Arthroplasty

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Introduction:

Many total hip arthroplasty (THA) studies have discussed the ideal target for acetabular cup position to avoid hip dislocation, since cup orientation can be measured on a conventional radiograph. However, there is growing evidence that femoral stem position is just as important as cup position in a successful THA, and it would be valuable to preoperatively predict postoperative femoral stem anteversion. There is limited information on femoral stem anteversion postoperatively, since it requires three-dimensional imaging, such as computed tomography (CT) and biplanar radiographs (EOS imaging), which can capture both the proximal and distal femoral landmarks. We describe a simple method for measuring preoperative femoral neck cut anteversion and hypothesize it will correlate well to final femoral stem anteversion in a large series of patients undergoing cementless THA.

Methods:

We identified 76 patients who underwent primary unilateral THA with Mako® robotic-arm assisted technology (Stryker, Mahwah, NJ). All cementless THAs were performed with the same femoral stem design (Accolade II femoral stem, Stryker, Mahwah, NJ). Each patient underwent a preoperative CT scan (including the hip and distal femur) and standing biplanar hip-to-ankle radiographs (EOS Imaging System, Paris, France). The surgeon templated the location of the femoral neck cut on the preoperative anteroposterior hip radiograph. The corresponding transverse CT image at the location of the neck cut was used to measure the femoral neck axis. Then femoral neck cut anteversion was measured on the CT scan as the angle between the femoral neck axis and the posterior condylar axis (Fig. 1). Patients underwent standing biplanar hip-to-ankle radiographs 6 weeks postoperatively (Fig. 2), and final femoral stem anteversion was measured using sterEOS® software (EOS Imaging).

Results:

Femoral stem anteversion was significantly correlated with neck cut anteversion (simple linear regression R = 0.66; p<0.01; Fig. 3). Final femoral stem anteversion varied from 6° retroversion to 39° retroversion, with an average of 14° ± 10° for all patients. Figures 1 shows the CT method for measuring femoral neck cut anteversion in a 65 year old female, found to be 12°. Figure 2 shows postoperative biplanar radiographs of the same THA patient, where final femoral stem anteversion was 10°.

Conclusions: This method may provide surgeons with the ability to preoperatively predict final femoral stem anteversion after THA. Future research will consider how combined anteversion (both acetabular and femoral anteversion) impacts THA stability.

Figures

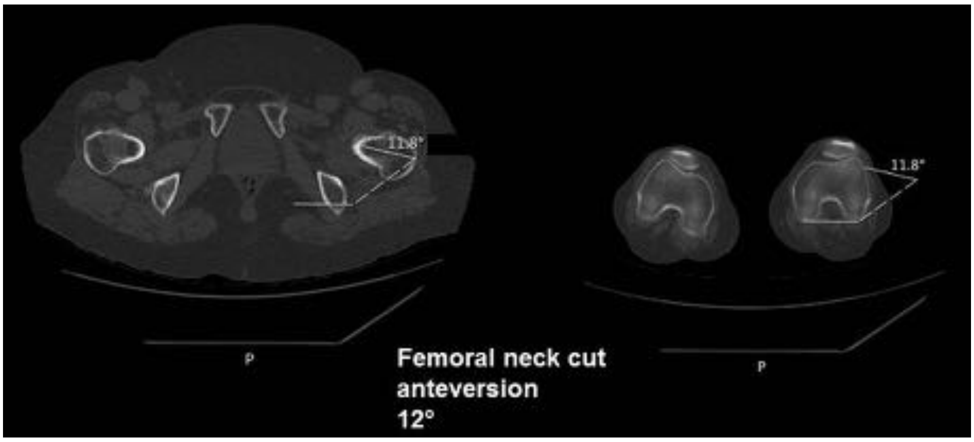

Figure 1

Figure 2

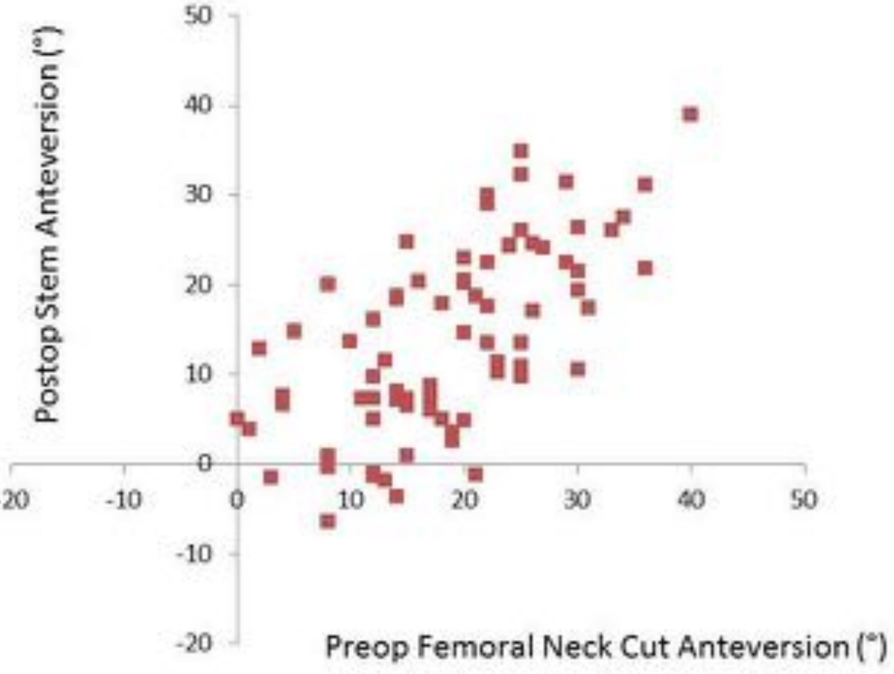
Postop Stem Anteversion (°)
Preop Femoral Neck Cut Anteversion (°)
50
40
30
20
10
0
-10
-20
-20
-10
0
10
20
30
40
50

Figure 3

#5943

Three-Dimensional Analysis of Contact Area and Ratio Between Acetabular Component and Bone According to Cup Inclination and Anteversion in Revision Arthroplasty

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Abstract

Preoperative planning for revision THA is very important for the choice of implant, bone graft, and surgical method. The most commonly used acetabular classification system was described by Paprosky, and classifies the type of acetabular defect based on a plain AP pelvic radiograph. However, the contact area and ratio between the acetabular component and host bone cannot be accurately measured on a plain radiograph alone, and the type of acetabular defect is likely to be misjudged. Therefore, we investigated the following: (1) the main and interaction effects among 5 variables (medialization, cup inclination, cup anteversion, quadrant, and type of acetabular defect) for the contact area and ratio, (2) the angle changes in cup inclination and anteversion causing significant differences in contact area and ratio, and (3) differences in the contact ratio according to type of acetabular defect.

Fifty patients who underwent revision THA in our hospital were first classified using the Paprosky system based on a simple AP pelvic radiograph. Measuring the contact area and ratio between the acetabular component and inner surface of acetabulum was performed in the following 7 steps: (1) defining the reference plane and acetabular sphere, (2) cup insertion and positioning, (3) cup filling, (4) cup rotation and translation, (5) finding the contact area, (6) defining cup plane and dividing each contact volume, and (7) measuring contact area and ratio between cup and inner surface of acetabulum.

The main effects of medialization, cup inclination, cup anteversion, and quadrant were significantly different. However, the effect of type of acetabular defect was not. The overall effect of cup inclination on the contact area and ratio declined from 35° to 45°, and was not significantly different at each level of cup anteversion. The contact area and ratio were also not significantly different according to the small change of angle (2°) when cup inclination and anteversion were 35° and 10°, respectively. However, if the change in angle was large (4° in cup inclination and 6° in cup anteversion), there were significant differences in the contact area and ratio. Mean expected contact ratio between whole cup and acetabulum by type of acetabular defects were as follows; (1) type 1: 42.3%, (2) type 2A: 34.9%, (3) type 2B: 34.6%, (4) type 2C: 30.1%, (5) type 3A: 29.4%, and (6) type 3B: 25.6%. The interaction effect of 6 (cup inclination) × 6 (cup anteversion) × 6 (type of acetabular defects) was significant. However, further post-hoc analysis of the three-way interaction was not conducted. The interaction effects of 6 (cup inclination) × 6 (cup anteversion) × 2 (medialization) and 6 (cup inclination) × 6 (cup anteversion) × 4 (quadrant) were not significantly different.

In summary, overall, the smaller the cup inclination and anteversion, the larger the contact area and ratio. There was a significant difference for contact area and ratio when a change occurred over a specific angle. In addition, the contact ratio by type of acetabular defect between the acetabular component and host bone was likely to be different from that in a previous study.

#5767

The Influence of Sagittal Pelvic Rotation on the Functional Cup Orientation When Transverse Acetabular Ligament as an Intraoperative Guide for Cup Position

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Introduction

Optimal positioning of the acetabular component is essential to the success of a total hip arthroplasty (THA). Transverse acetabular ligament (TAL) as an intraoperative anatomical landmarks of orientation guide possess the characteristics of patient-specific, reproducible, and independent of patient position. Several studies demonstrated that TAL can be used to direct the position of acetabular component. In the situation of using TAL as a guide for cup position, the functional cup inclination based on the radiograph in the standing position is less to report. The aim of this study is to analyze how pelvic mal-rotation in standing posture influence the functional cup position in this situation.

Methods

From March 2016 to March 2017, the clinical and radiographic data of 98 patients who underwent primary THA in our institution were retrospectively analyzed. There were 41 men and 57 women of average age 51.6 years (range 19-65) at the time of surgery. Functional anteversion and inclination of the acetabular component were measured on standing anteroposterior pelvic radiographs. Pelvic rotation was assessed by the obturator foramen (OF) ratio, which was defined as the tallest height over the widest width of the right obturator foramen.We define that the OF ratio between 0.3 to 0.8 was pelvic neutral position, between 0.8 to 1.5 was mild pelvis backward tilt(10°~30°), lager than 1.5 was apparent backward tilt(lager than 30°). According to the OF ratio, we divided the patients into 3 groups (Group A: normal pelvis; Group B: mild tilt; Group C: apparent tilt). Functional anteversion and inclination of the acetabular component out of "safe zones" were recorded and compared in 3 groups. The demographic data, clinical results and complications of patients were also reviewed.

Results

There were 42 patients in Group A, 31 in Group B and 25 in Group C. The mean angle of anteversion for Group C (21.5°; 13° to 30°) was significantly larger than Group B (18.1°; 8° to 25°) and Group A (16.1°; 6° to 23°) . The mean angle of inclination for Group C (48.1°; 32° to 61°)was significantly larger than Group A (44.1°; 28° to 54°). However, There was no difference of inclination between Group B and Group C. The rate of functional anteversion out of "safe zones" in Group C(21.2%) is significantly larger than Group A(6.5%) and Group B (15.4%). However, The rate of functional inclination out of "safe zones" was no difference in three group. Three of 25 patients (12%) in Group C had an anterior dislocation 4 weeks post-operatively. Two of 31 patients (6%) had an anterior dislocation within 4 weeks after surgery and no patient had dislocation in Group A.

Conclusions

Pelvic rotation on standing position significant influence the functional cup position and clinical result of THA when using TAL as a guide for cup position.

#5806

Can We Refer to the Contralateral Side for Restoring Coronal Plane Alignment in Reconstructive Knee Surgery?

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Introduction: The principle of constitutional varus alignment is generally accepted, but its consequences to the development of osteoarthritis and treatment options are still debated. In the absence of information about the pre-disease alignment status in varus osteoarthritis of the knee, some surgeon may rely on the measurements of the unaffected contralateral limb in order to plan or to verify surgical realignment procedures or arthroplasty. The purpose of this radiographic study is twofold: first to analyse the similarity of the coronal plane in the contralateral lower limb, as we expect that both legs have roughly the same alignment. Secondly do we want to define how reliable we can base our joint replacements and joint line reconstructions upon this contralateral sided knee.

Materials and Methods: Full leg standing radiographs of 250 asymptomatic volunteers were reviewed for three alignment parameters. Reliability was tested by intervals around the right knee alignment with 0,5° increments both to varus and valgus, resulting in the formation of intervals which enlarged with a 1 degree span. Subsequently, it was considered whether or not the left knee alignment was part of this interval.

Results: 28 persons (11%) had bilateral constitutional varus alignment and 51 (20%) had an unilateral constitutional varus aligned lower lower limb. Only 55% of the left knees were retained in the 3° interval (+/- 1,5° varus-valgus) around the right knee. This number increases to 86% when using a 6° interval.
Conclusion: Constitutional varus alignment is only present bilaterally in only a third of the population who have at least one constitutional varus aligned lower limb. The contralateral limb has a low predictive value to derive the alignment in a young and asymptomatic population, its use is limited in an arthritic knee where deviations of alignment due to arthritic disease progression are pronounced.

Level of Evidence: Level I, diagnostic study

#6178

Are Supine Intraoperative and Standing Biplanar Postoperative Radiographic Measurements of Acetabular Cup Position the Same?

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Background:

Supine positioning during direct anterior approach total hip arthroplasty (DAA THA) facilitates use of fluoroscopy, which has been shown to improve acetabular component positioning on plane radiograph. This study aims to compare 2-dimensional intraoperative radiographic measurements of acetabular component position with RadLink to postoperative 3-dimensional SterEOS measurements.

Methods:

Intraoperative fluoroscopy and RadLink (El Segundo, CA) were used to measure acetabular cup position intraoperatively in 48 patients undergoing DAA THA. Cup position was measured on 6-week postoperative standing EOS images using 3D SterEOS software and compared to RadLink findings using Student's t-test. Safe-zone outliers were identified. We evaluated for measurement difference of > +/- 5 degrees.

Results:

RadLink acetabular cup *abduction* measurement (mean 43.0°) was not significantly different than 3D SterEOS in the *anatomic plane* (mean 42.6°, p = 0.50) or in the *functional plane* (mean 42.7°, p = 0.61) (Fig. 1-2). RadLink acetabular cup*anteversion* measurement (mean 17.9°) was significantly different than 3D SterEOS in both the *anatomic plane* (mean 20.6°, p = 0.022) and the*functional plane* (mean 21.2°, p = 0.002) (Fig. 3-4). RadLink identified two cups outside of the safe-zone. However, SterEOS identified 12 (anatomic plane) and 10 (functional plane) outside of the safe-zone (Fig. 5-7). In the *functional plane*, 58% of anteversion and 92% of abduction RadLink measurements were within +/- 5° of 3D SterEOS.

Conclusion:

Intraoperative fluoroscopic RadLink acetabular *anteversion* measurements are significantly different than 3D SterEOS measurements, while *abduction* measurements are similar. Significantly more acetabular cups are placed outside of the safe-zone when evaluated with 3D SterEOS versus RadLink.

Figures

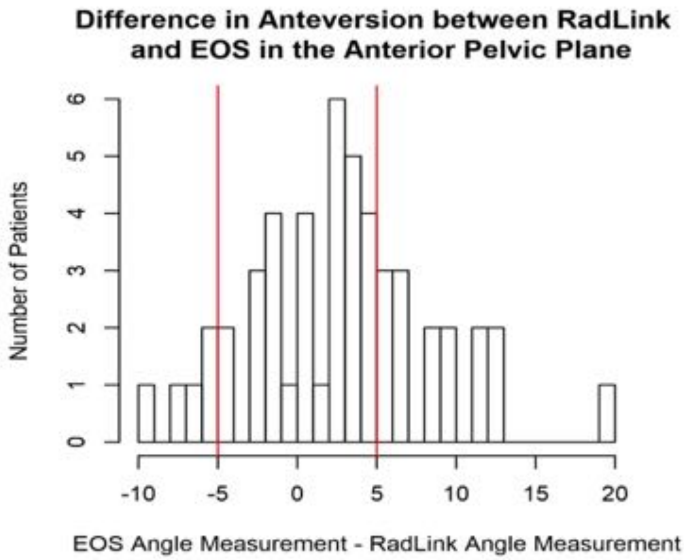

Figure 1

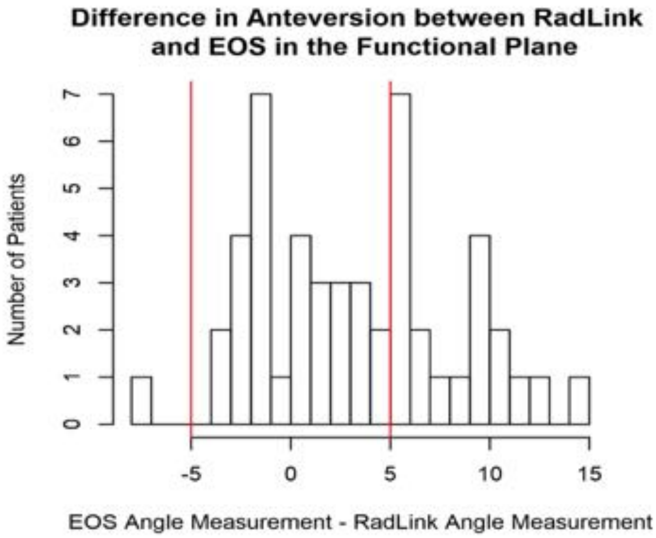

Figure 2

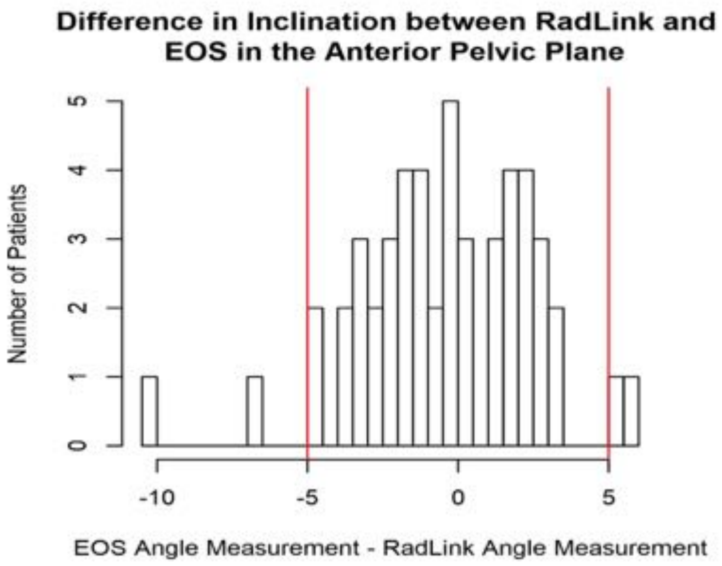

Figure 3

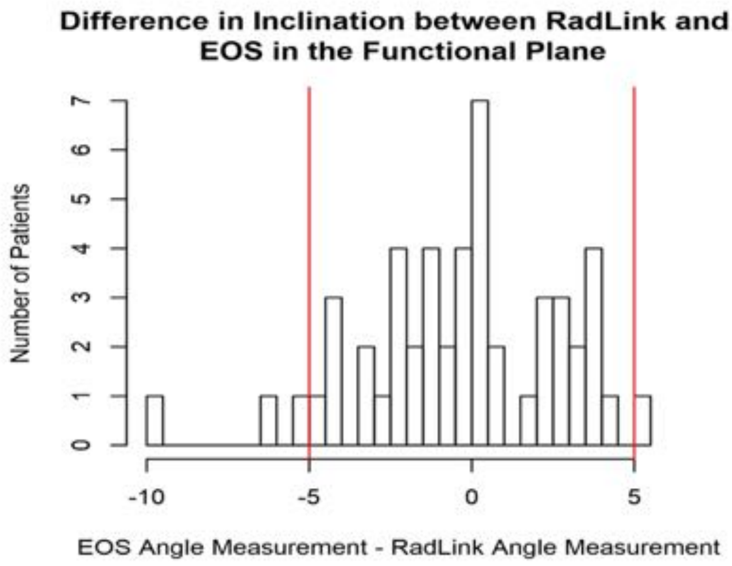

Figure 4

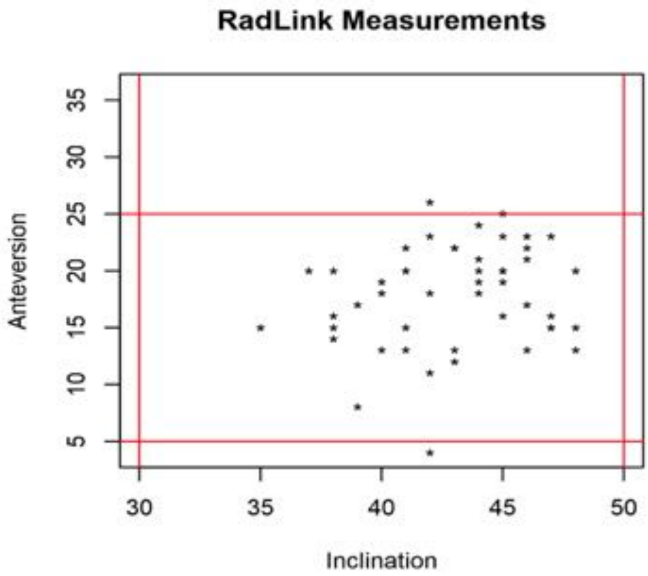

Figure 5

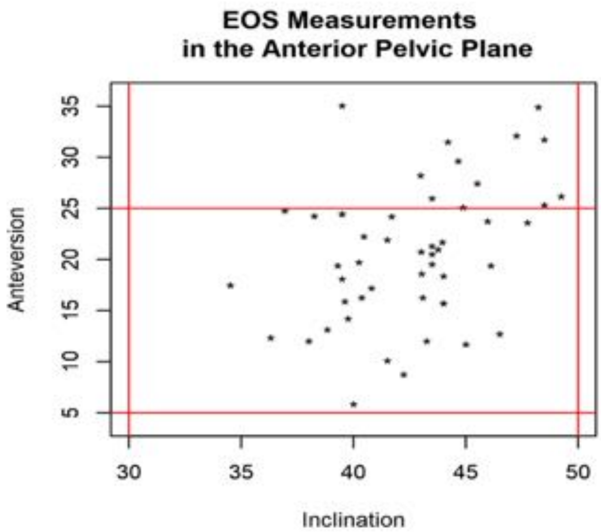

Figure 6

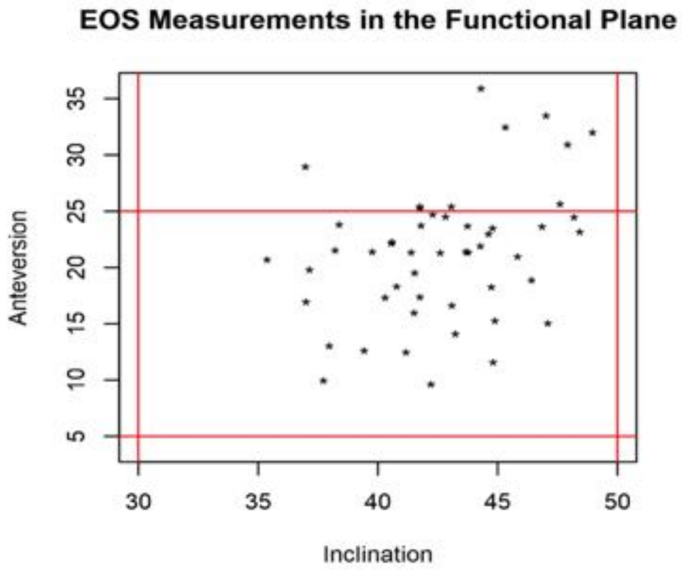
EOS Measurements in the Functional Plane
Anteversion
35
30
25
20
15
10
5
30
35
40
45
50
Inclination

Figure 7

#6017

Six-Degree-of-Freedom Kinematics of Posterior-Stabilised, Cruciate-Retaining and Medial-Stabilised Knee Implants in Overground Walking

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INTRODUCTION

The medial-stabilised (MS) knee implant, characterised by a spherical medial condyle on the femoral component and a medially congruent tibial bearing, was developed to improve knee kinematics and stability relative to performance obtained in posterior-stabilised (PS) and cruciate-retaining (CR) designs [1, 2]. We aimed to compare in vivo six-degree-of-freedom (6-DOF) kinematics during overground walking for these three knee designs.

METHODS

Seventy-five patients (42 males, 33 females, age 68.4±6.6 years) listed for total knee arthroplasty (TKA) surgery were recruited to this study, which was approved by the relevant Human Research Ethics committees. Each patient was randomly-assigned a PS, CR or MS knee (Medacta International AB, Switzerland) resulting in three groups of 23, 26 and 26 patients, respectively. Patients visited the Biomotion Laboratory at the University of Melbourne 6±1.1 months after surgery, where they walked overground at their self-selected speed. A custom Mobile Biplane X-ray (MoBiX) imaging system tracked and imaged the implanted knee at 200 Hz. The MoBiX system measures 6-DOF tibiofemoral kinematics of TKA knees during overground gait with maximum RMS errors of 0.65° and 0.33 mm for rotations and translations, respectively [3].

RESULTS AND DISCUSSION

Mean walking speeds for the three groups were not significantly different (PS, 0.86±0.14 m/s CR, 0.82±0.17 m/s and MS, 0.87±0.14 m/s, $p>0.25$). While most kinematic parameters were similar for the PS and CR groups, mean peak-to-peak anterior drawer was greater for PS (9.89 mm) than CR (7.75 mm, $p=0.004$), which in turn was greater than that for MS (4.43 mm, $p<0.001$, Fig. 1). Mean tibial external rotation was greater for MS than PS (by 3.12°, $p=0.033$) and CR (by 3.34°, $p=0.029$). Anterior drawer and lateral shift were highly coupled to external rotation for MS but not so for PS and CR. The contact centres on the tibial bearing translated predominantly in the anterior-posterior direction for all three designs (Fig. 2). Peak-to-peak anterior-posterior translation of the contact centres in the medial compartment was largest for PS (7.09 mm) followed by CR (5.45 mm, $p=0.003$) and MS (2.89 mm, $p<0.001$). The contact centre in the lateral compartment was located 2.5 mm more laterally for MS than PS and CR ($p<0.001$) (Fig. 2, inset). The centre of rotation of the knee in the transverse plane was located in the medial compartment for MS and in the lateral compartment for both PS and CR.

CONCLUSIONS

This is the first study to measure and quantitatively compare in vivo 6-DOF joint motion for PS, CR, and MS knees during locomotion. A higher degree of coupling between external rotation and anterior-posterior translation, greater constraint in the anterior-posterior direction, and a more medialised joint centre of rotation observed for the MS knees are explained by the highly congruent medial articulation characterising this design.

ACKNOWLEDGEMENTS

Medacta International AB, Switzerland

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Figures

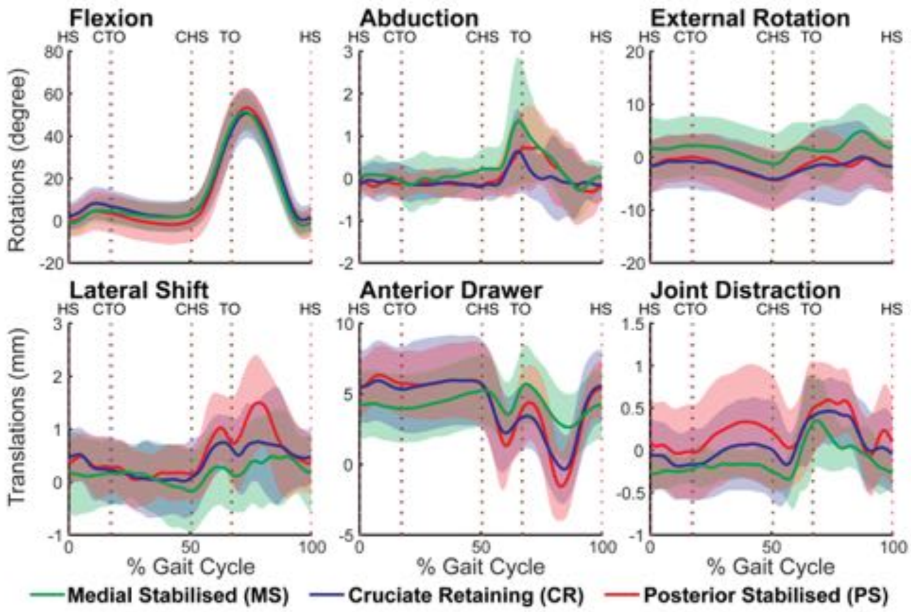

Figure 1. Displacements of the tibia relative to the femur for one cycle of overground walking for posterior stabilised (PS, red), cruciate retaining (CR, blue) and medial stabilised (MS, green) TKA designs. HS, heel-strike; TO, toe-off; CHS, contralateral heel-strike; CTO, contralateral toe-off.

Figure 1

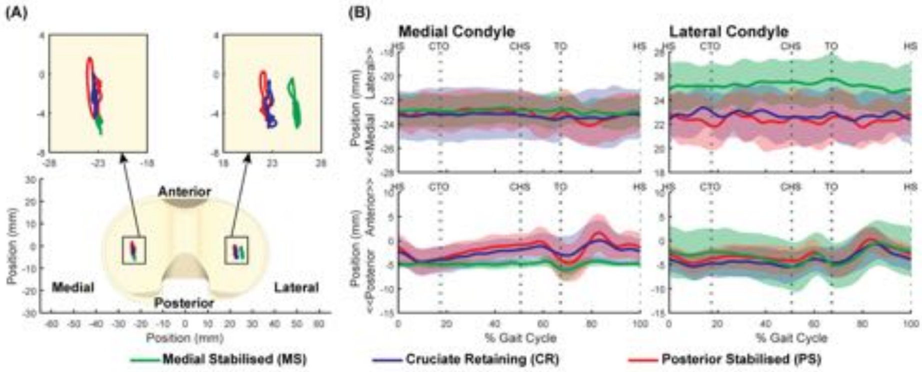

Figure 2. Location of the contact centres on the tibial bearing for posterior stabilised (PS, red), cruciate retaining (CR, blue) and medial stabilised (MS, green) TKA designs for one cycle of overground walking. (A) Tibial bearing along with contact centres as viewed from above. The insets show detailed views of the paths of the contact centres on the tibial bearing.
(B) Medial-lateral and anterior-posterior translations of the contact centres on the medial and lateral plateaux of the tibial bearing plotted against time, which is represented as a percentage of the gait cycle.

Figure 2

#5583

Kinematically Aligned Total Knee Arthroplasty Reduces Frontal Plane Knee Adduction Moment During Gait

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Background: Deviation of the tibial component from neutral mechanical alignment has been considered a risk factor for aseptic loosening, and varus alignment has been assumed to increase external knee adduction moment (KAM). This study aimed to examine the effects of joint line obliquity in kinematically aligned total knee arthroplasty (KA-TKA) on frontal plane knee kinetics, including KAM.

Methods: This study enrolled 21 knees from 18 patients who underwent KA-TKA in our institute. A matched control group of 21 knees from 18 patients undergoing MA-TKA served as controls. The only inclusion criterion was end-stage knee osteoarthritis with varus deformity. CT scan was performed preoperatively, and the data were reconstructed into 3-dimensional models using ATHENA software (SoftCube, Osaka, Japan), and preoperative planning for KA-TKA was performed. Gait analysis was performed the day before TKA and at a mean of 2.2 years postoperatively for KA-TKA and 2.9 years postoperatively for MA-TKA (overall mean, 2.6 years postoperatively). All subjects performed trials of 10-m level walking at a comfortable walking speed in a gait laboratory without shoes. Knee kinematics and ground reaction force (GRF) were measured using a Pro-reflex system (120 frames/s; Qualysis, Savedalen, Sweden) and an AM6110 force plate (frequency 600 Hz, sample frequency synchronized to 120 Hz; Bertec, Columbus, OH). Six retro-reflective markers were placed directly onto the skin of the subject. KAM was calculated using an inverse dynamics approach with original software, and was normalized by body weight (BW) X height.

Results: Baseline knee kinematics and kinetics prior to TKA was similar between the KA- and MA-TKA groups. In the KA-TKA group, the proximal tibia was resected in 3.4±1.5º of varus relative to the mechanical axis of the tibia. Final limb alignment measured as the mean femorotibial angle (FTA) was 176.7º with KA-TKA and 174.4º with MA-TKA. KAM at the first peak was significantly smaller in KA-TKA than in MA-TKA, and delta KAM was significantly larger in KA-TKA than in MA-TKA. Regarding the variables affecting KAM, significant differences between groups were evident in knee adduction angle ($p=0.002$), lever arm ($p=0.03$), and delta lever arm ($p<0.0001$). In addition, delta KAM correlated strongly with delta lever arm in both groups ($r=0.87$, $p<0.000001$ for KA-TKA; $r=0.68$, $p=0.00068$ for MA-TKA).

Conclusions: According to our study, the first peak of KAM during gait was greatly reduced in KA-TKA compared to MA-TKA, despite slightly varus limb alignment in KA-TKA. Reduced KAM in KA-TKA can tolerate the slight constitutional varus alignment common in Asian populations.

#5789

Is There a TKA Bearing Design Which Can Be Used for a Cruciate Sacrificing and Cruciate*

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Introduction: Total-knee-arthroplasty (TKA) is a well-established method to restore the joint function of the human knee. Different types of TKA designs are clinically available which can be divided in two main groups, the posterior-cruciate-ligament (PCL) sacrificing and retaining group. However, pre-operatively it is often difficult to plan for one or the other. Therefore, the research question was: Is it possible to develop a TKA bearing design which works for both the cruciate sacrificing and retaining technique. A medial-congruent (MC) bearing design was developed, characterized by a high medial sagittal conformity and lower lateral sagittal conformity, which can be used for both cruciate ligament states. This study compares the laxity and kinematics of this MC design to a contemporary PS design for the cruciate sacrificing technique and to a contemporary CR design for the cruciate retaining technique.

Methods: Four specimen-specific computer models of the human knee, consisting of a femur, tibia and fibula bone as well as the contribution of the ligaments and capsule, were virtually implanted with three TKA designs in four constellations: 1) MC without PCL, 2) MC with PCL, 3) contemporary PS without PCL and 4) contemporary CR with PCL following the design specific surgical technique and tibia slopes. Laxity tests in internal-external rotation (moment ± 4 Nm) were performed with the implanted models for a weight bearing case (500N compression). In addition, a high demanding activity (lunge) was simulated. The resulting averaged laxities and kinematics were analysed and compared to each other.

Results: When sacrificing the PCL, MC showed lower medial laxity throughout flexion and higher lateral laxity above 60° flexion compared to the PS design (Figure 1). When retaining the PCL, the MC resulted in lower medial laxity throughout flexion, lower lateral laxity in extension and similar lateral laxity in flexion compared to the CR design. When sacrificing the PCL in the lunge activity, the MC design had a more posterior position throughout flexion on both condyles until deep flexion when the engagement of the cam/spine occurred for the PS design and posterior motion of the medial condyle during mid-flexion as opposed to anterior motion for the PS design (Figure 2). When retaining the PCL in the lunge-activity, the MC design had a more posterior position throughout the activity, and similar medial and lateral condyle motion throughout flexion compared to the CR design.

Conclusion: When sacrificing the PCL, MC behaved similar to a contemporary PS design with more medial stability, more lateral laxity in deep flexion, and a posterior position during a lunge activity that did not depend on a cam/spine mechanism. When retaining the PCL, MC behaved similar to a contemporary CR design with more medial stability, similar lateral laxity in deep flexion, and a posterior position during a lunge activity demonstrating that the increased medial conformity did not cause a kinematic conflict with the retained PCL. These findings illustrate the concept that the MC design can be used for both the PCL sacrificing and retaining technique.

*Computer-Models are not necessarily indicative of clinical results.

Figures

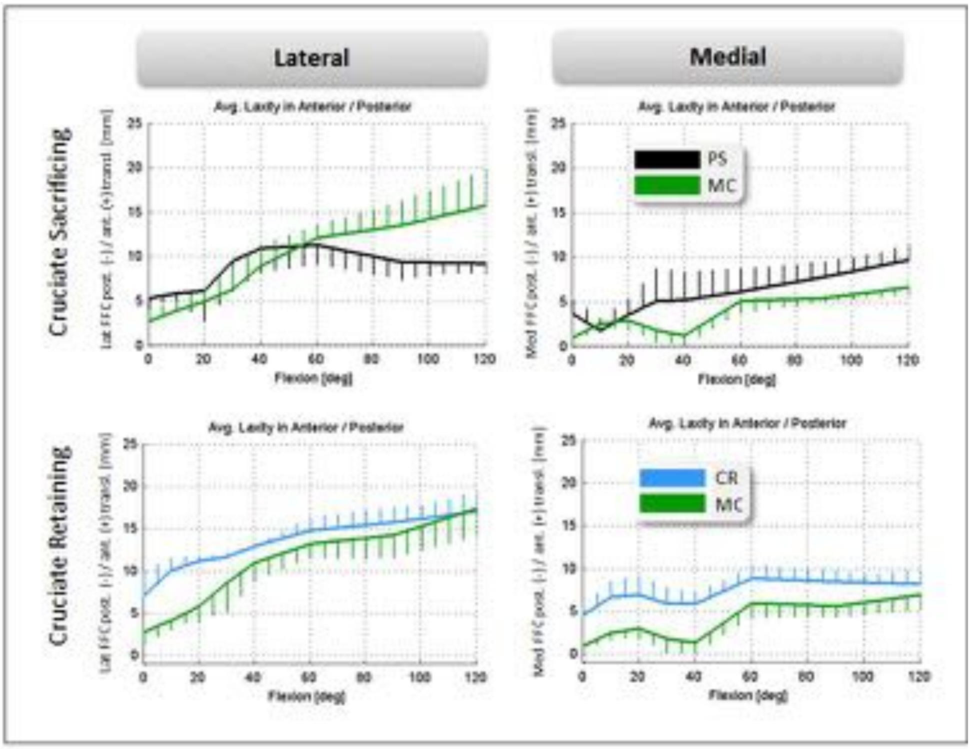

Figure 1: Averaged laxity in AP during IE rotation.

[Figure 1](#)

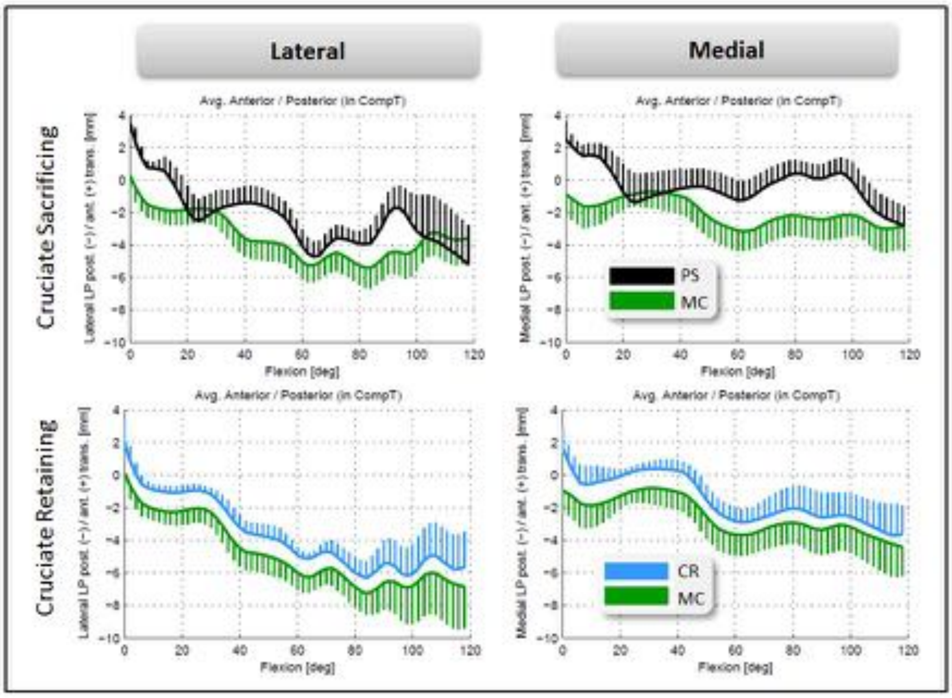

Figure 2: Average medial and lateral AP kinematics of the Lowest Points (LP) during lunge activity.

[Figure 2](#)

#5731

Influence of Gradually Reducing Femoral Radii in Total Knee Arthroplasty on in Vivo Tibiofemoral Kinematics During Daily Activities: A Videofluoroscopy Study

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Introduction

For total knee arthroplasties (TKA) the reproduction of the tibio-femoral kinematics of the healthy knee is considered to be beneficial. Thereby the knee is thought to show a medial pivot with a lateral femoral rollback during flexion [1]. In contrast, in posterior cruciate ligament retaining TKAs, several authors have reported a sudden anterior slide, also referred to as paradoxical anterior translation, of the femoral condyle relative to the tibial component [2-4].

Reduced paradoxical anterior translation in mid-flexion has been reported for femoral components with gradually reducing radius when compared to a two-radii design based on FE model simulations and in vitro tests [4], as well as intraoperatively [5] and recently also in vivo during a lunge and unloaded flexion-extension [6]. The kinematic task dependency of TKA [7] necessitate the investigation if the previous shown reduction of paradoxical anterior translation by gradually reducing femoral radii can also be confirmed during gait activities.

Therefore, the aim of the study was to evaluate and compare the three-dimensional in vivo kinematics of the cruciate retaining (CR), fixed bearing (FB) Attune^{TM} TKA featuring a gradually reducing femoral radii and the dual-radii TKA design PFC Sigma Curved CR FB during daily activities by means of videofluoroscopy.

Methods

26 good outcome subjects with unilateral Attune^{TM} CR FB TKA (69±9y, BMI 28±4kg/m2, KOOS 89±9, n=15, DePuySynthes) and Sigma CR FB TKA (70±8y, BMI 26±4kg/m2, KOOS 93±5, n=11, DePuySynthes), were assessed at least one year postop during five complete cycles of level walking and stair descent (0.18m steps), a deep knee bend and sitting down onto and standing up from a chair using a moving fluoroscope (25Hz, 1ms shutter time) [8]. 2D/3D registration of the 2D fluoroscopic images was performed using CAD models of the implant components [9]. Tibio-femoral anterioposterior (AP) translations were described using the nearest points of the femoral condyles relative to the tibial baseplate and normalized to a medium implant size.

Results

Ranges of motion (ROM) for flexion/extension, ab-/adduction, internal/external rotation as well as AP translation were similar for the Attune^{TM} and the Sigma subjects, whereas the pattern of AP translation-flexion-coupling differed between the Sigma and the Attune^{TM} (Fig. 1, Fig. 2). The Sigma showed a sudden change of direction of AP translation around 30° of flexion (Fig. 1), which was not present in the Attune^{TM} (Fig. 2). Tibial internal rotation with increasing flexion was present in average over all subjects for both TKAs except for level walking, for which rotation stayed rather constant (Fig. 3).

Conclusions

The present data confirms that the gradually reducing femoral radii eliminated the paradoxical sudden anterior translation at 30° present in the dual-radii design in vivo during daily activites. The gradually reducing femoral radii improved lateral femoral rollback during the sit tasks as well as above 30° also for the gait activities.

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[2] doi:10.1097/01.blo.0000062385.79828.72

[3] doi:10.1302/0301-620X.88B8.17529

[4] doi:10.1016/j.jbiomech.2013.01.025

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[8] doi:10.1371/journal.pone.0185952

[9] doi:10.1109/TMI.2005.846849

Figures

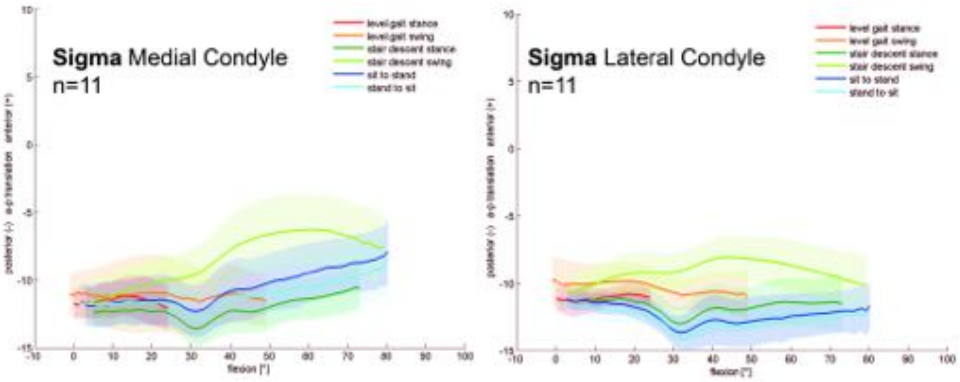


Figure 1

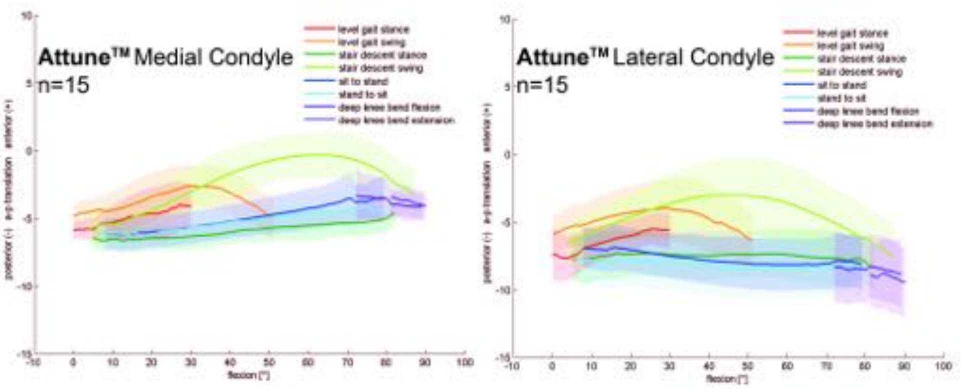
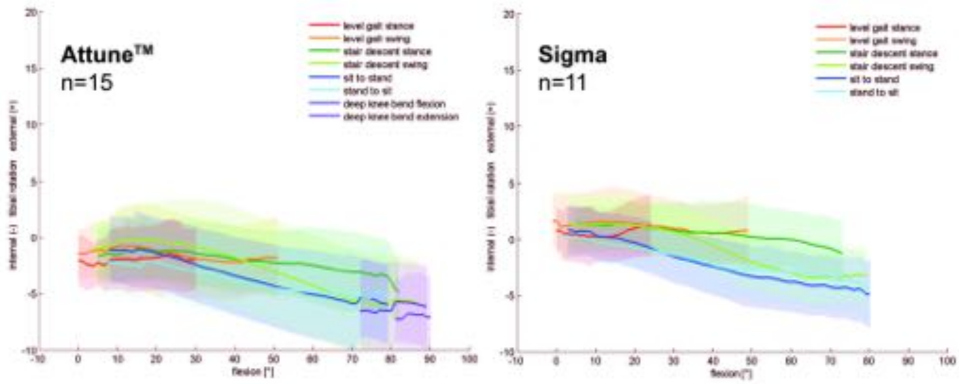


Figure 2



Attune™
n=15
level gait stance
level gait swing
stair descent stance
stair descent swing
sit to stand
stand to sit
deep knee bend flexion
deep knee bend extension
internal (-) tibial rotation external (+)
flexion [°]
Sigma
n=11
level gait stance
level gait swing
stair descent stance
stair descent swing
sit to stand
stand to sit
internal (-) tibial rotation external (+)
flexion [°]

Figure 3

#5800

Muscle Activity in TKA Patients While Ascending and Descending a Ramp

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Many patients who undergo a total knee arthroplasty (TKA) wish to return to a more active lifestyle following surgery. The implant must be able to restore adequate muscle strength and function. However, this may not be a reality for some patients as previous research has suggested that quadriceps and hamstrings muscle activity may remain impaired following surgery.

The purpose of this study was to compare muscle activity between TKA patients and controls (CTRL) during ramp ascent and ramp descent walking tasks.

A total of 15 patients were assigned to either a MP or PS TKA operated by the same surgeon. Approximately 9 months following surgery, the 15 patients along with nine CTRL patients completed a 3D motion and EMG analysis during a level, ramp ascent & ramp descent walking tasks.

Wireless EMG electrodes were placed on six muscles: vastus medialis (VM), vastus lateralis (VL), biceps femoris long head (BF), semimembranosus (SM) muscles, gastrocnemius medial head (GM), and gastrocnemius lateral head (GL). Participants completed three trials of each condition.

All EMG data were processed for an entire gait cycle of the operated limb in the TKA group, and for the dominant limb in the CTRL group. The maximum muscle activity achieved with each muscle during the level trial was used to normalize the ramp ascent & descent trials. The onset and offset of each muscle was determined using the approximated generalized likelihood ratio which the active muscle duration was calculated.

Peak muscle activity (PeakLE EMG), total muscle activity (iEMG), muscle onsets/offsets and the active muscle duration were determined for each muscle for the ramp ascent and descent trials. Non-parametric Kruskal Wallace tests were used to test for statistical significance between groups with $\alpha=0.05$.

During the ramp up task, the TKA group had significantly greater PeakLE and iEMG for the hamstring muscles compared to the CTRL, whereas PeakLE for the VL muscle was lower in the TKA group. The onset of the VM muscle was significantly earlier in the gait cycle in the TKA.

During the ramp down task, the TKA group had significantly greater PeakLE and iEMG for all the muscles except the GM. The offset for the SM and onset for the VL muscles were significantly later in the gait cycle for the TKA group.

Stability in a cruciate removing TKA is partially controlled by the prosthetic design. During the ramp up task, the TKA group compensated the tibial anterior translation by activating their hamstrings more and for a longer duration.

During the ramp down task, TKA patients stiffened their knee in order to stabilize the joint. The quadriceps and GL muscle were also more activated and for a longer duration than the CTRL group to protect the tibial posterior translation.

Even if surgery reduced pain, differences in muscle activity exist between TKA patients and healthy controls. Although the prosthetic design bring some stability to the knee, we think that lack of proprioception, apprehension and the different stabilization pattern lead to muscles compensation and potential negative feeling for the patient.

Figures

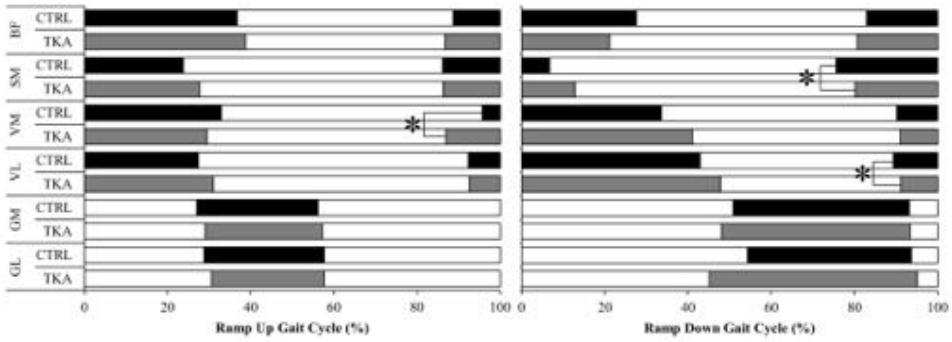

Figure 1

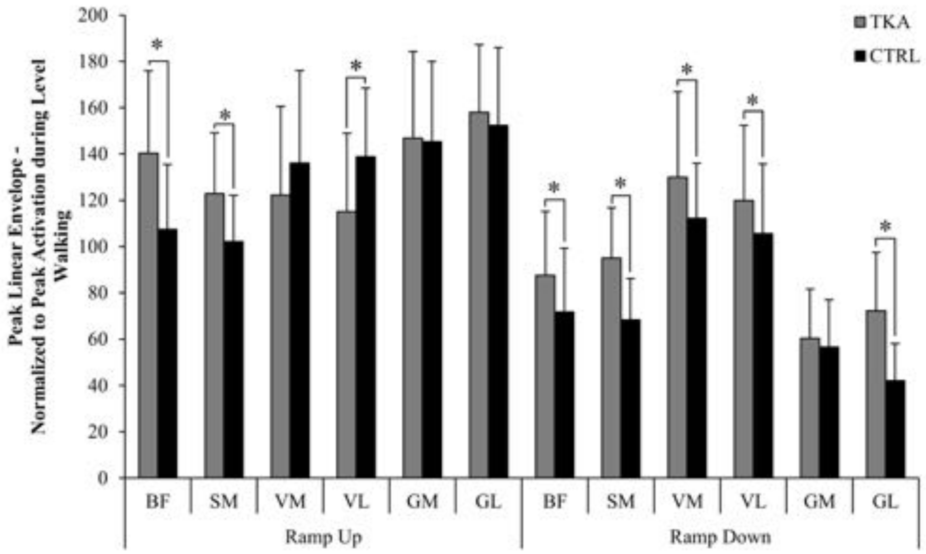

Figure 2

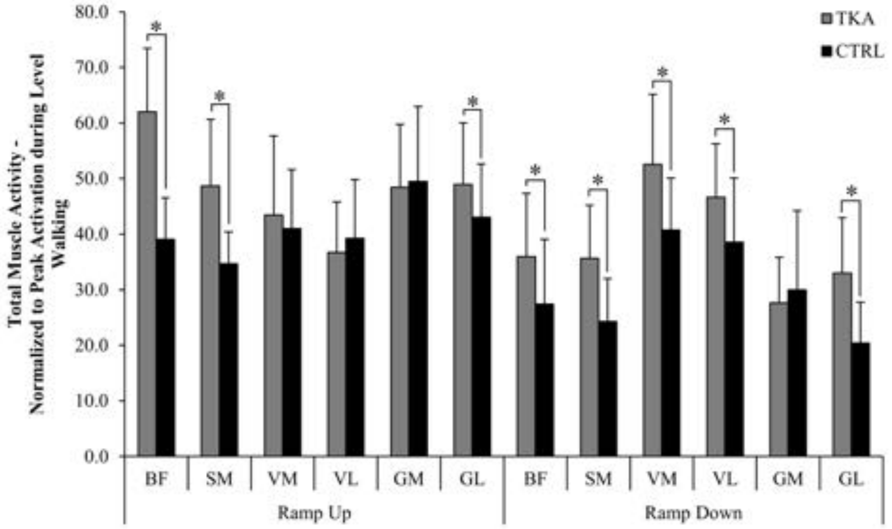

Figure 3

#5949

Does ACL Retention in TKR Affect Knee Biomechanics During Level Walking and Stair Ascent?

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Introduction:

This study explores whether patients with bicruciate retaining TKRs (BiCR) have more normal knee biomechanics during level walking and stair ascent than subjects with posterior cruciate retaining TKRs (PCR). Due to anterior cruciate ligament (ACL) preservation, we expect BiCR subjects will not show the reduced flexion and altered muscle activation patterns characteristic of persons with TKRs.

Methods:

Motion and electromyography (EMG) data were collected during level walking and stair climbing for 16 BiCR subjects (4/12 m/f, 65±3 years, 30.7±7.0 BMI, 8/8 R/L), 17 PCR subjects (2/15 m/f, 65±7 years, 30.4±5.1 BMI, 7/10 R/L), and 17 elderly healthy control subjects (8/9 m/f, 55±10 years, 25.8±4.0 BMI, 10/7 R/L), using the point cluster marker set. Surface EMG electrodes were placed on the vastus medialis obliquus (VMO), rectus femoris (RF), biceps femoris (BF), and semitendinosus (ST) muscles. EMG data are reported as percent relative voluntary contraction (%RVC), normalized to the average peak EMG signals during level walking. Statistical nonparametric mapping was used for waveform analysis.

Results:

Both TKR groups were older, and PCR subjects had higher BMI than control subjects ($p \le 0.020$). The BiCR group walked slower and with shorter stride lengths than controls ($p \le 0.012$). During level walking (Figure 1), BiCR subjects had less knee extension and posterior tibial displacement than controls (95-98%, 96-100% gait cycle, p=0.003, 0.001). PCR subjects showed less extension mid-stance than controls (36-44% gait cycle, p=0.001) and more external rotation (66-69% gait cycle, p=0.003). Both TKR groups had smaller extension moment peaks (PCR 5, 59-75, 96%, BiCR 61-78, 95-97% stance, $p \le 0.007$, 0.003) than the control group. The BiCR group had smaller adduction and external rotation moment peaks (20-24%, 10-18% stance, p=0.003, 0.001) compared with controls.

During stair climbing (Figure 2), BiCR subjects displayed more external tibial rotation (4-16% stance), more knee abduction (36-52% stance), and a lower adduction moment peak (24-34% stance) compared to healthy controls ($p \le 0.005$). TKR subjects from both groups showed lower flexion moment peaks than controls (PCR 24-35%, BiCR 24-28% stance, $p \le 0.001$, 0.004). For EMG (Figure 3), PCR subjects had more BF activity during stair ascent versus level walking than healthy subjects (56-74% stance, $p \le 0.001$).

Discussion:

BiCR and PCR showed more similarities than expected. Both had altered kinematics and kinetics compared to controls, suggesting some intrinsic extensor mechanism weakness, possibly an aftereffect of osteoarthritis. The EMG results agreed accordingly, as both TKR groups showed (nonsignificant) decreased quadriceps activity during stair climbing (Figure 3a,b). Interestingly, PCR subjects showed more BF activity during stair than healthy controls, while BiCR BF co-contraction was more similar to controls' (Figure 3c). BiCR subjects also showed increased external rotation in early stance compared to the controls (Figure 2c), but began conforming to the controls' pattern as subjects reached about 45° flexion, at which angle the ACL typically engages, indicating that within its functional range, the ACL may normalize knee rotation for BiCR subjects. Although ACL retention in TKRs does not correct the extensor mechanism deficits commonly found in TKR patients, it does appear to normalize secondary knee kinematics and hamstring muscle co-contraction.

Figures

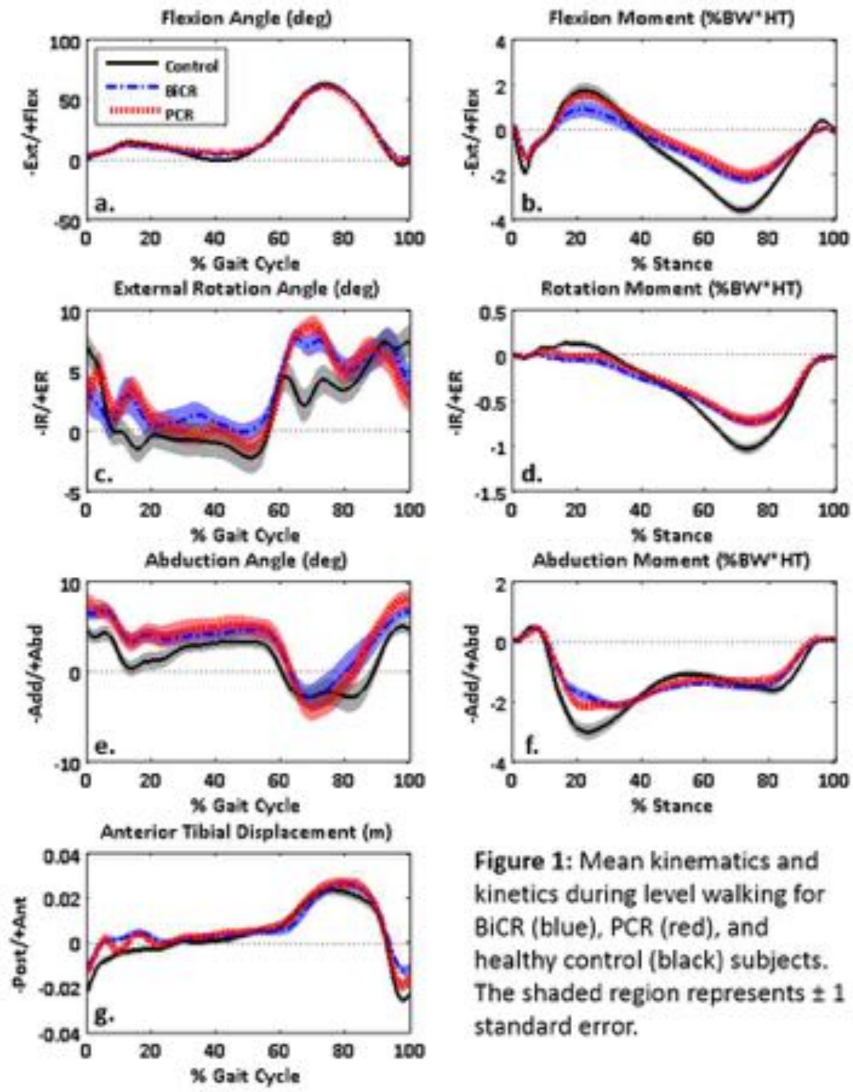

Figure 1: Mean kinematics and kinetics during level walking for BiCR (blue), PCR (red), and healthy control (black) subjects. The shaded region represents ± 1 standard error.

Figure 1

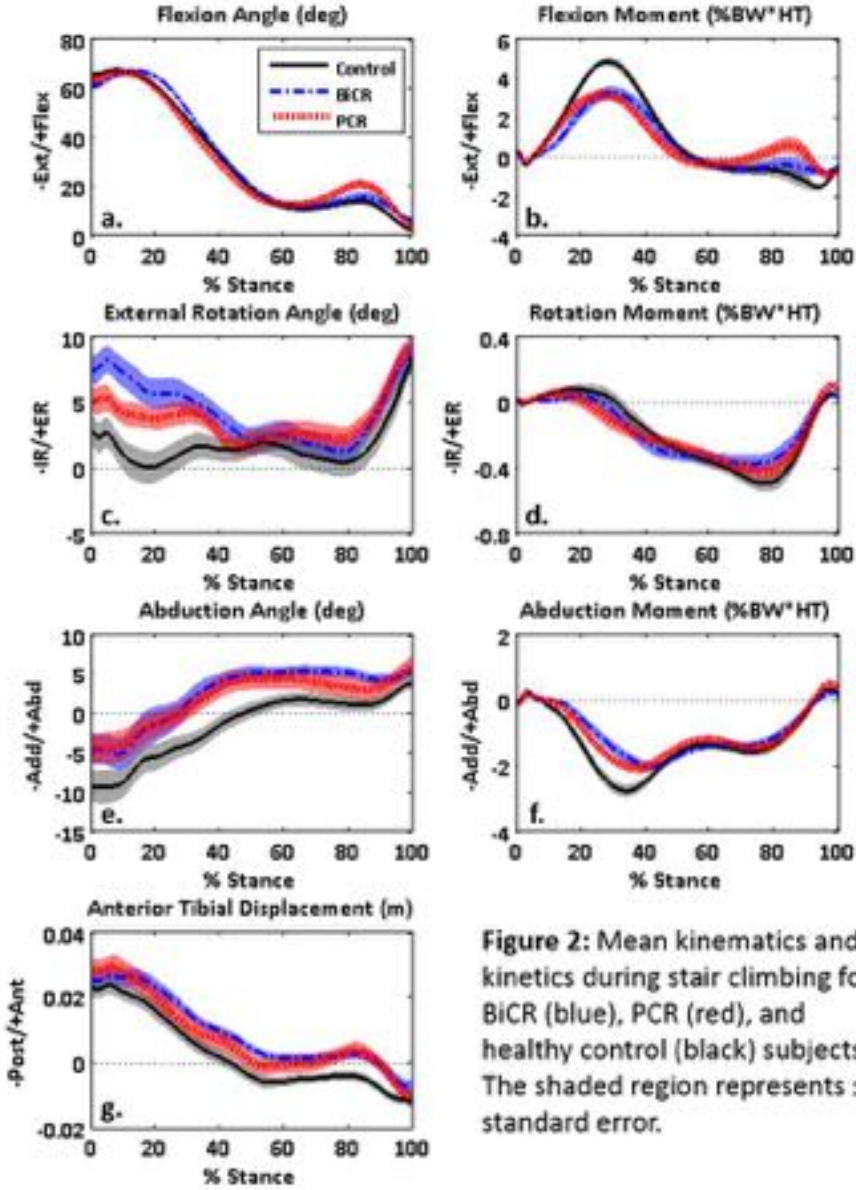

Figure 2: Mean kinematics and kinetics during stair climbing for BiCR (blue), PCR (red), and healthy control (black) subjects. The shaded region represents ± 1 standard error.

Figure 2

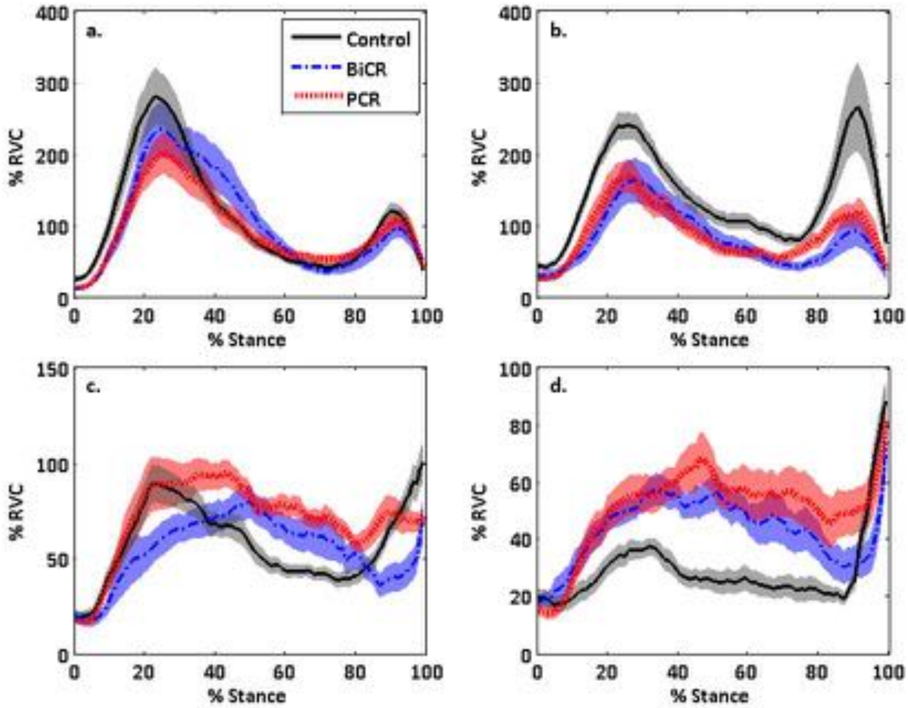

Figure 3: Mean EMG signal during stair climbing. The shaded region represents ± 1 standard error. Percent RVC was calculated by normalizing the stair EMG signal to the average peak EMG signal during level walking and multiplying by 100%.

Figure 3

#5876

Effect of Head Size on the Mechanical and Tribological Performance of Ceramic-on-Ceramic Bearings, Under Conditions of Adverse Surgical Positioning and Edge Loading

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Introduction and Aims

Edge loading has been associated with increased wear and damage in ceramic-on-ceramic bearings. Larger head sizes may reduce the risk of dislocation however the effect of head size on the severity of edge loading, damage and wear is not known. The aim of this study was to assess the effect of hip bearing diameter on the occurrence and severity of edge loading, damage and wear of ceramic-on-ceramic bearings

Methods

Two ceramic-on-ceramic (CoC) bearing sizes (28mm and 36mm BIOLOX® delta femoral head and liners, 48mm and 56mm liner outer diameter respectively, DePuy Synthes Joint Reconstruction) were used in this study. A new two-stage approach [1] for evaluating joint replacement was followed to assess the mechanical and tribological performance of CoC bearings using the Prosim EM13 (Figure 1). Stage one was a biomechanical study which included variations in rotational positioning (45°, 55° and 65° inclination angles) and translational mismatches in the medial-lateral axis (1, 2, 3 and 4 (mm)). In stage two of this study, the wear and damage were assessed by applying a standard gait cycle (ISO 14242-1) under two conditions: firstly with no mismatch between the head and the cup and secondly under edge loading condition driven by separation where a 4mm mismatch was introduced between the femoral head and the cup and the cup was inclined at steep inclination angle (equivalent to 65° *in vivo*). For stage one, each test (n=3) was run for a total of 500 cycles and the dynamic separation displacement between the head and cup was measured in the medial-lateral axis. For stage two, each conditions (n=6) was run for a total of three million cycles. The lubricant used was diluted new-born calf serum (25% v/v). Gravimetric wear assessment was completed using a microbalance and geometric changes were assessed using a coordinate measuring machine.

Results

The level of dynamic separation displacements were generally higher for the 36mm bearing compared to the 28mm bearings (Figure 2). This difference was most marked when testing was carried out with acetabular cups under 4mm of translational mismatch and at 65° of cup inclination. Under these conditions the mean dynamic separation (±95% confidence limits) of the 36mm femoral head was 2.8±0.2mm compared with that of the 28mm bearings which was 2.4±0.2mm. The mean wear rate for the 36mm CoC bearings (±95% confidence limits) under 4mm translational mismatch at three million cycles was 0.23±0.06 ± mm^3/million cycles. This was significantly lower ($p<0.01$) than that obtained for the 28mm bearings (0.68±0.18 mm^3/million cycles) when tested under the same conditions. The maximum penetration depth on the femoral heads (Figure 3) were also significantly lower ($p=0.03$) for the 36mm (22±3µm) bearings compared to the 28mm bearings (29±6µm).

Conclusions

Edge loading due to separation driven by variation in surgical positioning caused increased damage and wear in both size 28mm and 36mm ceramic-on-ceramic bearings. Larger head size (36mm) showed lower wear and damage on the surface compared to the 28mm bearings when tested under the same input adverse conditions.

References

[1] O'Dwyer Lancaster-Jones,et.al.2017,JBMR-B.

Figures

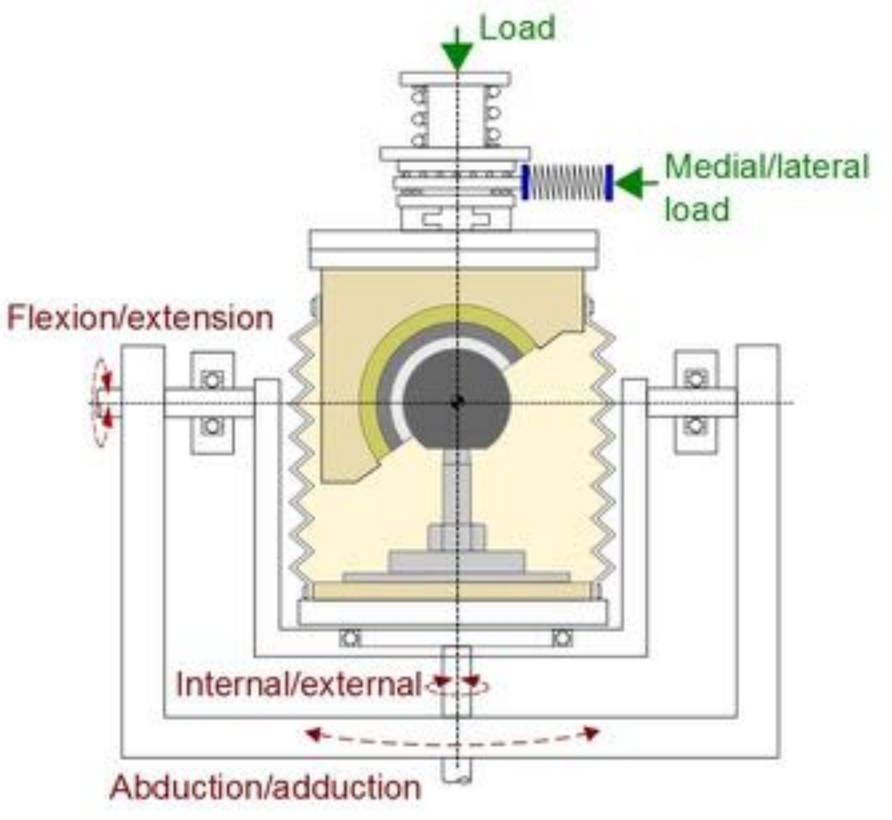

Figure 1: Schematic representation of one station of the six-station electromechanical hip joint simulator (EM13, ProSim, Simulation Solution, UK).

Figure 1

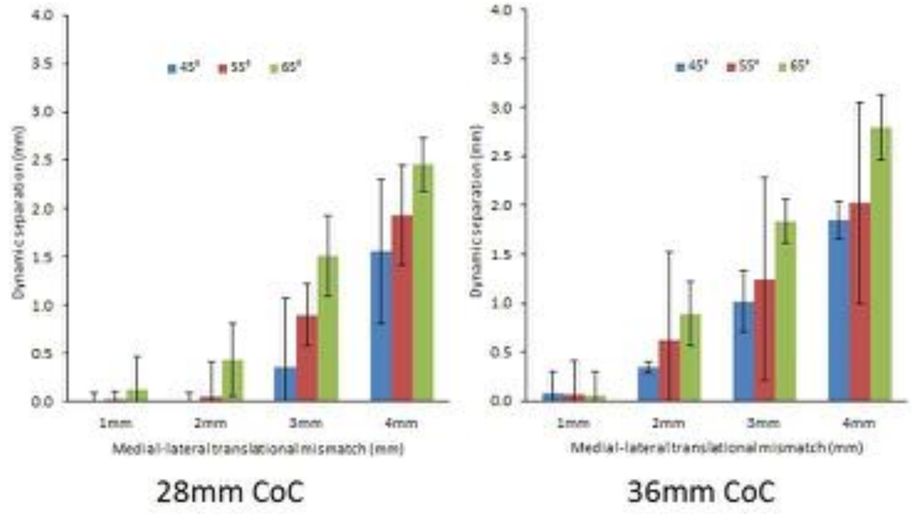

Figure 2: Mean dynamic separation displacement (±95% confidence limits) for 28mm and 36mm ceramic-on-ceramic bearings tested under 1-4mm translational mismatch with 45°, 55° and 65° cup inclination angle with 100N/mm spring constant and 70N swing phase load with ISO 14242-1 gait inputs.

Figure 2

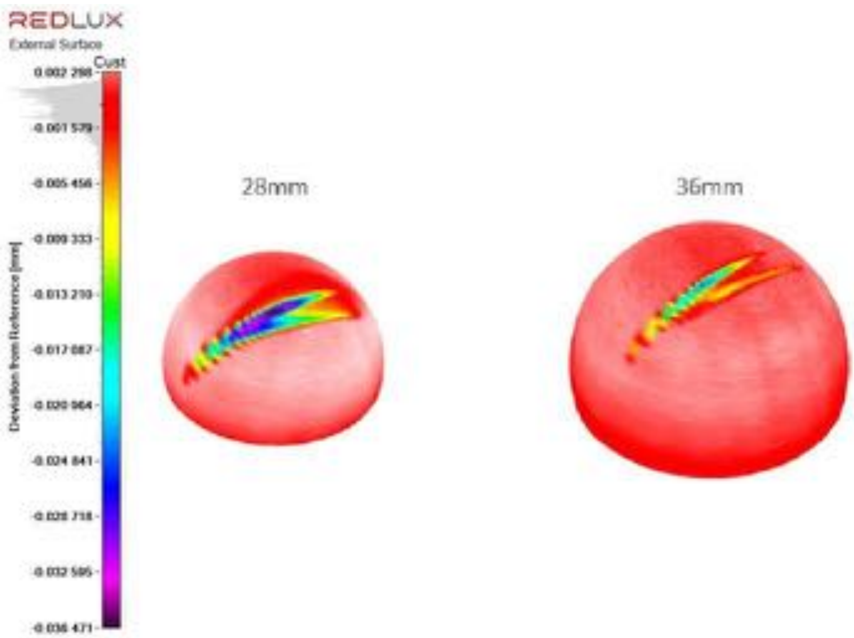

Figure 3: The damage observed on the ceramic femoral head for a 36mm and 28mm size heads due to edge loading driven by dynamic separation conditions

Figure 3

#5756

The Influence of Contact Pressure and Cross-Shear on the Wear of UHMPWE-on-PEEK-OPTIMA

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Introduction

PEEK-OPTIMA™ has been considered as an alternative to cobalt chrome in the femoral component of total knee replacements [1]. Wear simulation studies of both the tibiofemoral and patellofemoral joints carried out to date have shown an equivalent wear rate of UHMWPE tibial and patella components against PEEK and cobalt chrome (CoCr) femoral components implanted under optimal alignment conditions [1, 2]. In this study, fundamental pin-on-plate studies have been carried out to investigate the wear of UHMWPE-on-PEEK under a wider range of contact pressure and cross-shear conditions.

Methods

The study was carried out in a 6 station multi-axial pin-on-plate reciprocating rig. UHMPWE pins (conventional, non-sterile) were articulated against PEEK-OPTIMA™ plates, initial Ra ~0.02µm. The lubricant used was 25% bovine serum (17g/l) supplemented with 0.03% sodium azide. The contact pressure and cross-shear ratio conditions were selected to replicate those in total knee replacements and to be comparable to previously reported studies of UHMPWE-on-CoCr tested in the same pin-on-plate simulators [3]. Contact pressures from 2.1 to 25.5MPa were created by changing the diameter of the contact face of the pin, the cross-shear ratios ranged from 0 (uniaxial motion) to 0.18. Wear of the UHMWPE pins was measured gravimetrically and the surface topography of the plates assessed using a contacting Form Talysurf. N=6 was carried out for each condition and statistical analysis carried out using ANOVA with significance taken at $p<0.05$.

Results

When compared to conventional materials (UHMWPE-on-CoCr [3]), the wear factor of UHMPWE-on-PEEK was generally lower than that of moderately cross-linked UHMWPE-on-CoCr. With increasing contact pressure, there was a trend of decreasing wear factor and a significant difference ($p=0.001$) in the wear factor of the UHMPWE pins tested under different contact pressures. The wear of UHMWPE-on-PEEK followed a similar trend as that of UHMWPE-on-CoCr. Under uniaxial motion (cross-shear ratio = 0), the wear of UHMWPE was low, introducing multi-axial motion increased the wear of the UHMWPE. There was a significant difference ($p<0.01$) in the wear factor at different cross-shear ratios however, post hoc analysis showed only the test carried out under unidirectional motion to be significantly different from the other conditions tested.

At the conclusion of the studies, there was a polished region in the centre of the plate, however, there was no significant difference in the post-test surface roughness of the plate under any of the conditions tested.

Conclusion

The influence of contact pressure and cross-shear ratio on the wear of UHMWPE pins has shown a similar trend when articulating against either PEEK-OPTIMA™ or cobalt chrome plates. The wear factors determined in this study will provide inputs to future computational models which will allow the wear of this all-polymer knee replacement to be investigated under a wider range of clinically relevant conditions.

[1] Cowie RM, et al. 2016. JEIM 230(11):1008-1015

[2] Cowie, R. M., et al. 2018. *Orthopaedic Proceedings*. Vol. 100. No. SUPP_6. The British Editorial Society of Bone & Joint Surgery.

[3] Abdelgaied A, et al. 2012. JEIM 227(1):18-26

Figures

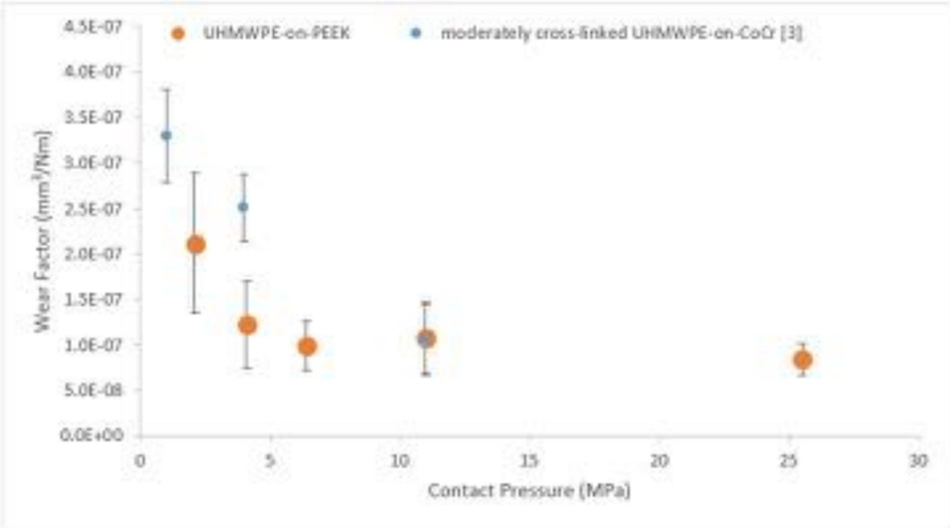

Figure 1: Mean wear factor (mm³/Nm) ± 95% confidence limits of UHMWPE-on-PEEK and moderately cross-linked UHMPWE-on-CoCr [3], cross-shear ratio 0.087, contact pressures from 2-25MPa, n=6.

Figure 1

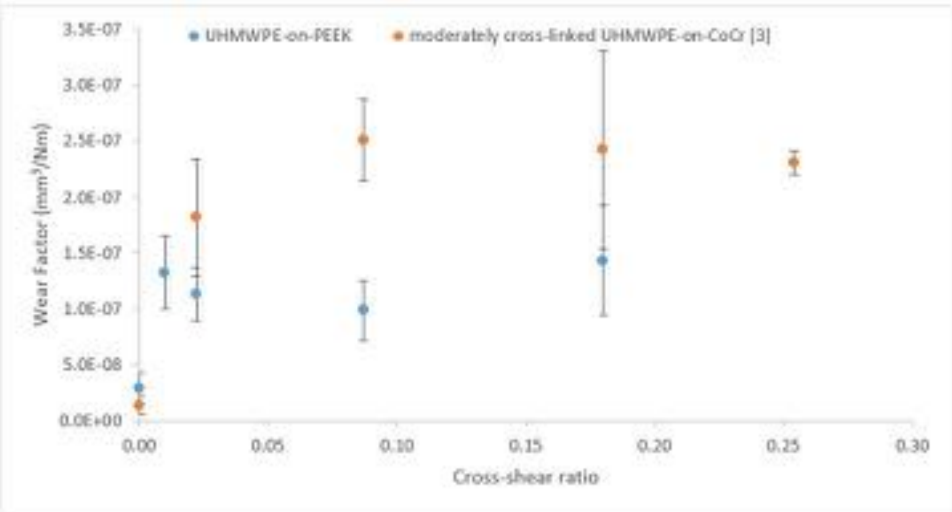

Figure 2: Mean wear factor (mm³/Nm) ± 95% confidence limits of UHMWPE-on-PEEK and moderately cross-linked UHMPWE-on-CoCr [3], contact pressure 4.1MPa, cross-shear ratios from 0 to 0.018, n=6.

Figure 2

#5607

Pin-on-Disc Tests to Search for a Material Well Suited to Articulate Against Cartilage and Subchondral Bone

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Introduction:

Hemiarthroplasty remains an acceptable alternative to total joint replacement in patients without osteoarthritic changes on the acetabular (hip) or glenoid (shoulder) side of the affected joint. However, often a significant erosion of the cartilage is observed [1]. At this stage, subchondral bone may become the articulating counterpart of the artificial femoral or humeral head. The present study elucidates the change in frictional behaviour when the counterpart of the hemiarthroplasty head material shifts from cartilage to bone in a pin-on-disc test set-up.

Methods:

A pin-on-disc tribometer test with a rotating disc and a sector-wise loaded pin was used to determine friction coefficients for different material pairings. The four pin materials porcine cartilage, subchondral bone of the porcine cartilage, UHMWPE, and vitamin E enhanced, cross-linked UHMWPE (VEPE). They were tested in combination with the three disc materials zirconia toughened alumina ceramic (ZTA), CoCr, carbon-fibre-reinforced carbon (CrC). Stepwise loading was employed with the forces 10 N, 5 N, 2 N and 1 N. Test duration was 1 h. Run-in was analysed with data acquired during the first 5 minutes, steady state with data from the last 10 minutes. Diluted calf serum according ISO 14242-1 was used to determine the friction coefficients. The surface topography of all pins was examined using optical profilometry before and after the rotation tribometer tests.

Results:

The coefficients of friction (COF) were lowest for the cartilage pins against all three disc materials, with steady-state values between 0.01 and 0.02 for the highest applied load (10 N). Run-in values were slightly higher. Friction of subchondral bone yielded COF in the range 0.2 to 0.6, depending on the counterpart material (Table 1 in Figure 1). The two polyethylene materials behaved similarly in this friction test with COF of about 0.1. No wear related modifications of the surface roughness parameters could be found (Figure 1). The Ra roughness values of the different pins reflect the COF results: Ra of subchondral bone was one order of magnitude higher than Ra of the cartilage.

Discussion & Conclusion:

The higher COF values of subchondral bone reflect the roughness Ra values of the bone being one order of magnitude higher than those of cartilage. An obvious interpretation therefore is purely physical nature: Higher roughness leads to higher friction. The COF of the PE materials is in-line with literature [2]. All three disc materials have similar COF when tested against cartilage. The differences, however, become more pronounced when articulating against subchondral bone, i.e. CrC exhibits markedly less friction than CoCr, a commonly used hemiarthroplasty head material. The ZTA ceramic lays between these two materials. - The sharp increase of friction when changing from cartilage to subchondral bone is a strong motivation to design a hemiarthroplasty head which does not degrade cartilage.

References:

[1] McGibbon CA et al. (1999) J Arthroplasty **14**:52–58

[2] Wintermantel E, Ha SH, 2009 *Medizintechnik 5th ed.*, Springer; p. 107.

Figures

Table 1
Coefficients of friction (COF) of the different disc materials against subchondral bone

Disc material	COF (steady state)
CoCr	0.6
ZTA	0.45
CrC	0.2

Figure 1

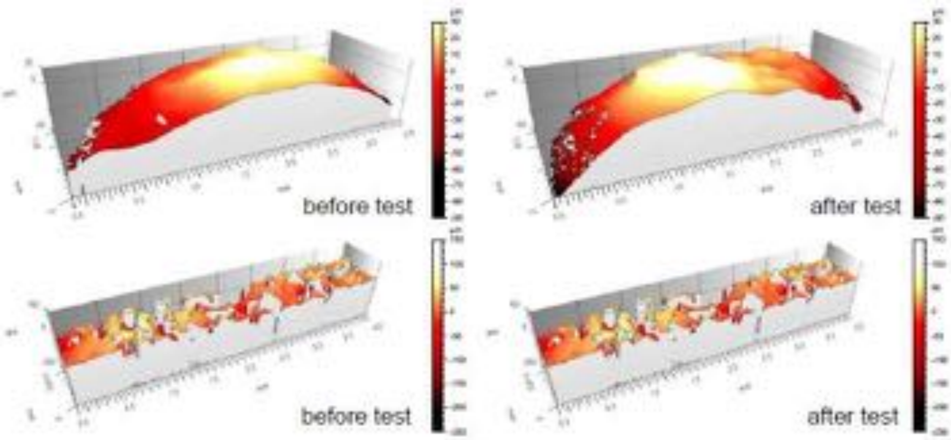

Figure 2

#5904

Metallic Wear Debris Isolation and Characterization: A Cadaver TKA Study

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Introduction: Metal release may be associated with adverse patient reactions in certain patients after total knee arthroplasty (TKA). However, little is known about the metallic periprosthetic wear debris from TKA. For this study, we asked: can we isolate metallic wear debris from cadaver TKAs using a method previously validated in animal models and what is the correlation between visible tissue metallosis and captured metallic debris?

Methods: The particle isolation methodology described by Patel et al. [1] was evaluated using the periprosthetic tissues collected from three deceased TKA patients at necropsy. The causes of death included cancer (n=1) and heart failure (n=2). Five tissue samples were collected per TKA, one each from the medial and lateral gutter, the inferior and superior patella, and the tibia, Figure 1. Tissues were digested following the previously-published enzymatic protocol [1] using papain and proteinase K followed by density gradient ultracentrifugation with sodium polytungstate, Figure 3. Samples were filtered onto polycarbonate membranes of 1 mm or 0.015 mm pore sizes. The 1 mm filters were rinsed with ethanol and weighed before and after filtration to determine the mass of particles 1 mm and larger. A 1 ml aliquot of the remaining solution was analyzed using nanoparticle tracking analysis (NTA; NanoSight, Salisbury, United Kingdom) to analyze the distribution of physiologically relevant particles. Scanning electron microscopy (SEM) images were taken to confirm particle recovery.

Results: All 15 of the tissue samples were successfully digested. The presence of metallic debris was confirmed by visual inspection of filters (Figure 3) and via SEM imaging. The median mean weight of debris captured on 1 mm filters was 0.5 ± 0.6 mg (range: 0-1.9 mg). The median mean particle size, as determined by NTA measurement, was 153.3 ± 64 nm (range: 39.1-332.8 nm). Four tissues had no visible metallosis, five tissues had a score of 3 for metallosis, and one tissue had a score of 5 with severe metallosis. The mean particle size did not correlate with tissue metal score, p=0.564. The weight of debris captured on the 1 mm filters did correlate with the tissue-metal score, p=0.039.

Discussion: Throughout this study, we sought to confirm that a validated particle recovery method previously used in animal models would also successfully isolate metal particles from human peri-prosthetic tissues. The use of this method allowed for almost complete recovery of clean isolated metallic particles. We also sought to correlate the isolated wear debris with visual characteristics of tissue metallosis. The larger wear debris correlated with visual metallosis, however, smaller more physiologically relevant debris did not.

References: [1] Patel et al. Acta biomaterialia, 2018, Volume 71, Pages 339-350.

Figures

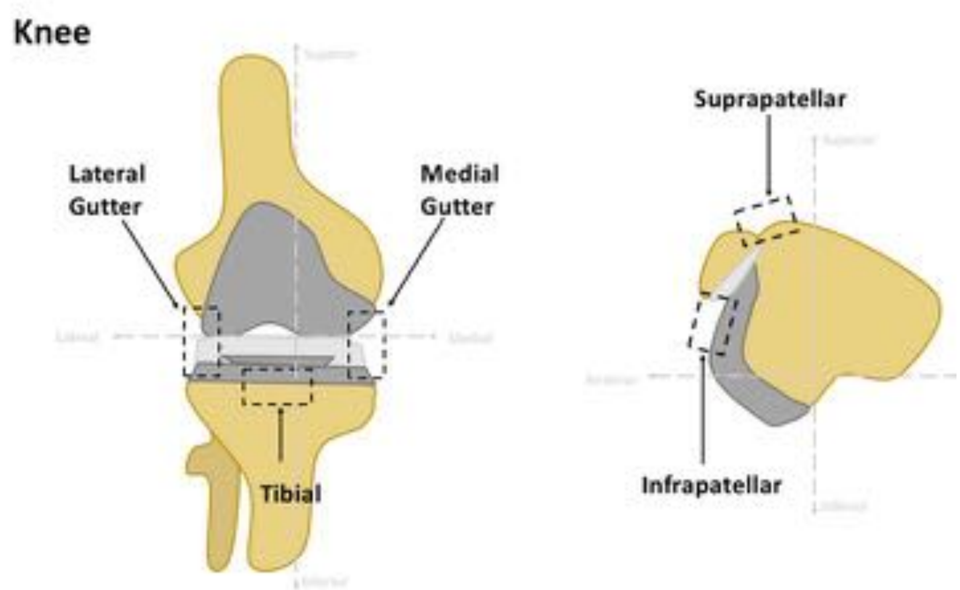

Figure 1: Schematic of total knee joint with identified regions for tissue collection.

Figure 1

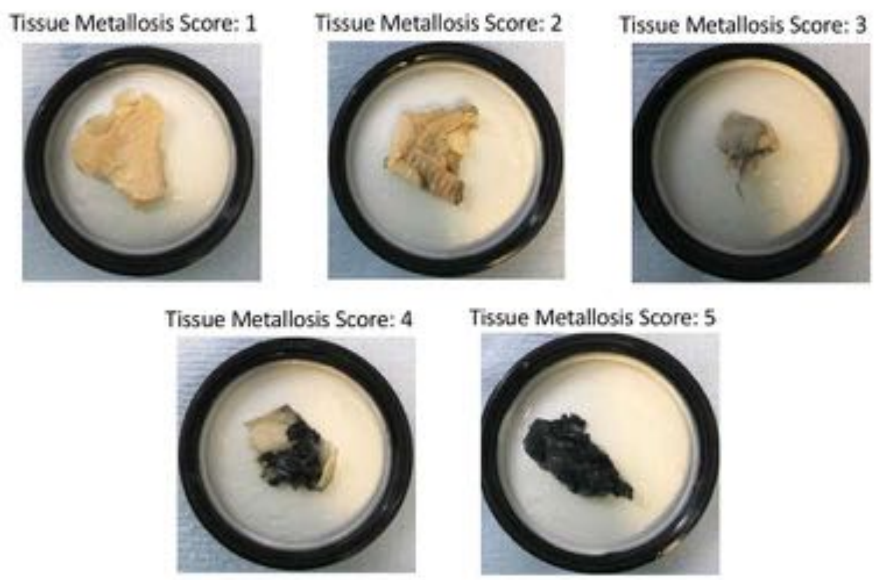

Figure 2: Pictorial description of tissue metal scoring system used to visually evaluate the degree of metallosis in peri-prosthetic tissue.

Figure 2

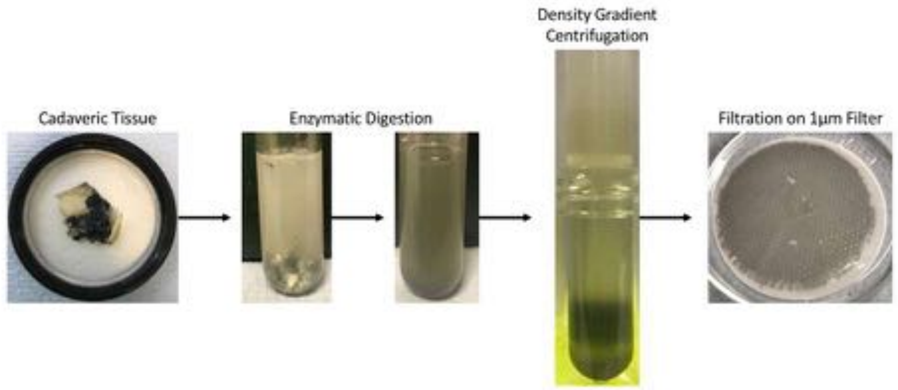

Figure 3: Description of protocol used to digest and isolate metallic debris from peri-prosthetic tissue in TKA.

Figure 3

#5875

The Influence of Different International Standards Organization (ISO) Control Regimes and Simulation Inputs on the Kinematics, Mechanics and Wear of a Total Knee Replacement

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Introduction: The number of young and more active patients requiring total knee replacement (TKR) is increasing. Preclinical evaluation and understanding the long-term failure of TKR is therefore important. Preclinical wear simulation of TKR is usually performed according to the International Standards Organization (ISO) recommendations. Two international standards for preclinical wear simulation of TKRs have been developed[1,2,3] so that the anterior-posterior (AP) translation and internal-external (IE) rotation can be driven in either force or displacement control. However, the effects of using different control regimes on the kinematics and wear of the same TKR have not been investigated. The current study investigated the kinematics, contact mechanics and wear performance of a TKR when running under ISO force and displacement control standards using an experimentally validated computational model.

Materials/Methods: Three different ISO control standards were investigated using a size C Sigma curved TKR (DePuy,UK), with moderately cross-linked UHMWPE curved inserts; ISO-14243-3-2004, ISO-14243-3-2014 and ISO-14243-1-2009. Axial force and flexion-extension angle are common for the three standards. AP and IE motions are displacement controlled in ISO-14243-3-2004 and ISO-14243-3-2014, with the only difference being a reversal of AP polarity between the two standards, and are force controlled in ISO-14243-1-2009 (Fig.1). The test setup and soft tissue constraints were defined in accordance with ISO recommendations[1,2,3]. The wear model was based on the modification of Archard's law where the wear volume is defined as a function of contact area, sliding distance, cross-shear and contact stress. The simulation framework has been independently validated against experimental wear rates under three different standard and highly demanding daily activities[4].

Results: Reversing AP in the displacement control ISO-2014, compared to ISO-2004, resulted in high contact stresses of more than 70 MPa in the posterior direction (Fig.2). The predicted AP and IE from the force control ISO-2009 were in different directions and magnitudes to ISO-2014 AP and IE (Fig.3). The predicted wear rates were 1.8, 2.0, and 5.5[mm^3/mc] for ISO-14243-3-2004, ISO-14243-3-2014 and ISO-14243-1-2009 respectively.

Discussion: Reversing AP in the displacement control ISO-2014, without revising the femoral centre of rotation, resulted in high stress edge loading in the posterior direction, due to femoral rollback, and more than 10% increase in wear rate compared to ISO-2004. The predicted AP and IE from the force control ISO-2009 had different polarities and magnitudes to the corresponding displacement control ISO-2014 AP and IE. In addition, the predicted wear rate under the force control ISO-2009 was more than double that measured under displacement control standards due to the increased AP and IE motions predicted under the force control standard. In addition to the previous validation of the model[4], the predicted wear rate under the force control ISO-2009 of 5.5mm^3/mc was within the 95% confidence limits of the reported experimental wear rate for the same TKR (4.71±1.29mm^3/mc)[5] which gives more confidence in the model.

Conclusion: The study showed significant differences between ISO force and displacement control standards and between ISO displacement standards with different

AP polarities. These differences should therefore be considered when choosing a control regime for preclinical simulation of TKR.

References: 1-ISO-14243-3,2004; 2-ISO-14243-3,2014; 3-ISO-14243-1,2009; 4-Abdelgaied et al.,JMBBM,2018; 5-Johnston et al.,ORS,2018

Figures

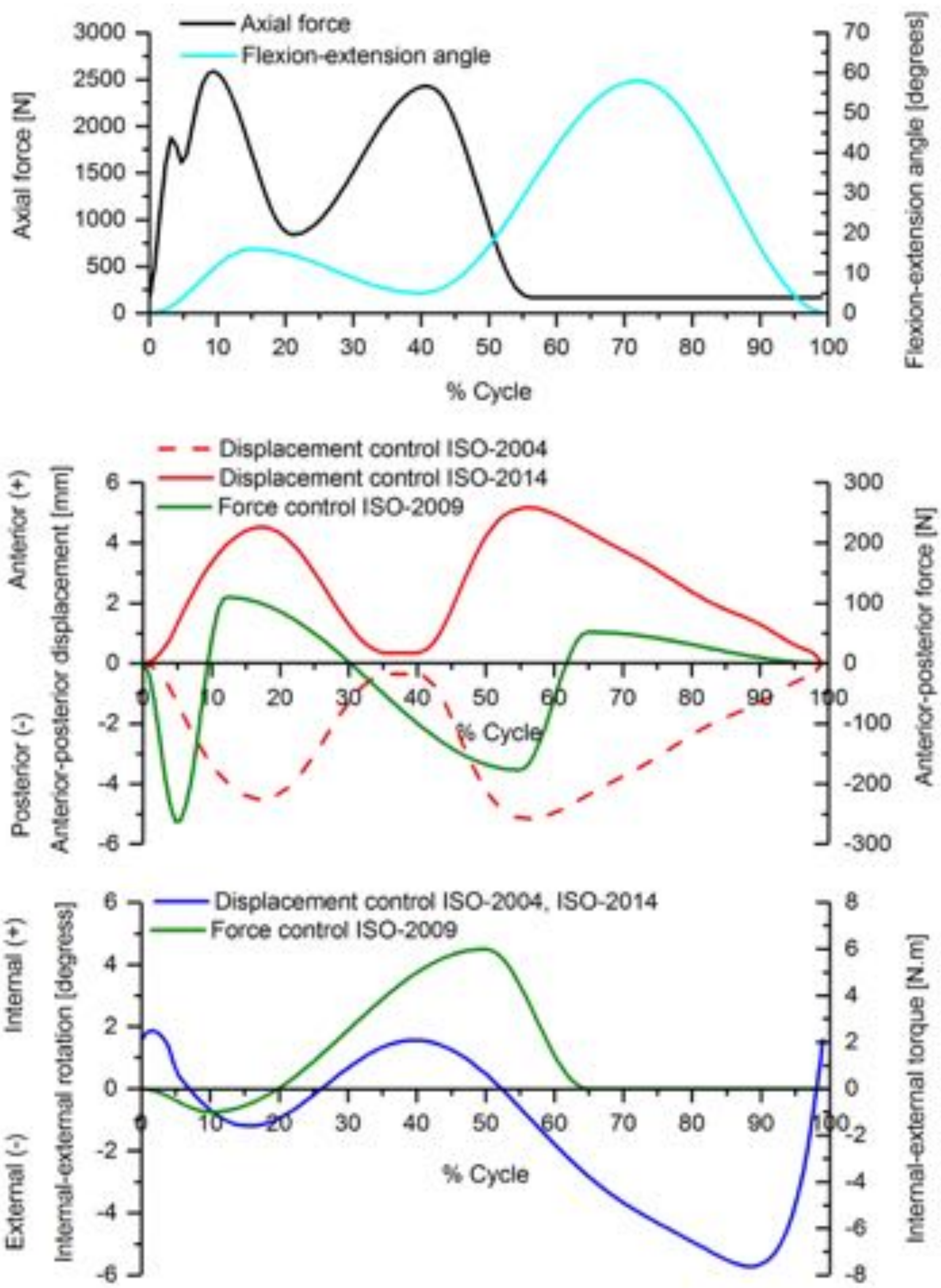

Fig.1: ISO displacement and force control standards

Figure 1

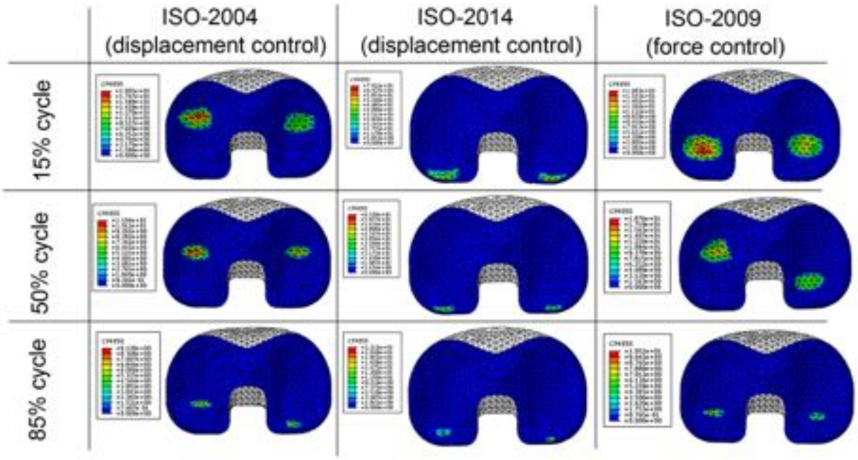

Fig.2: Predicted contact location and contact stress at 15%, 50% and 85% loading cycle

Figure 2

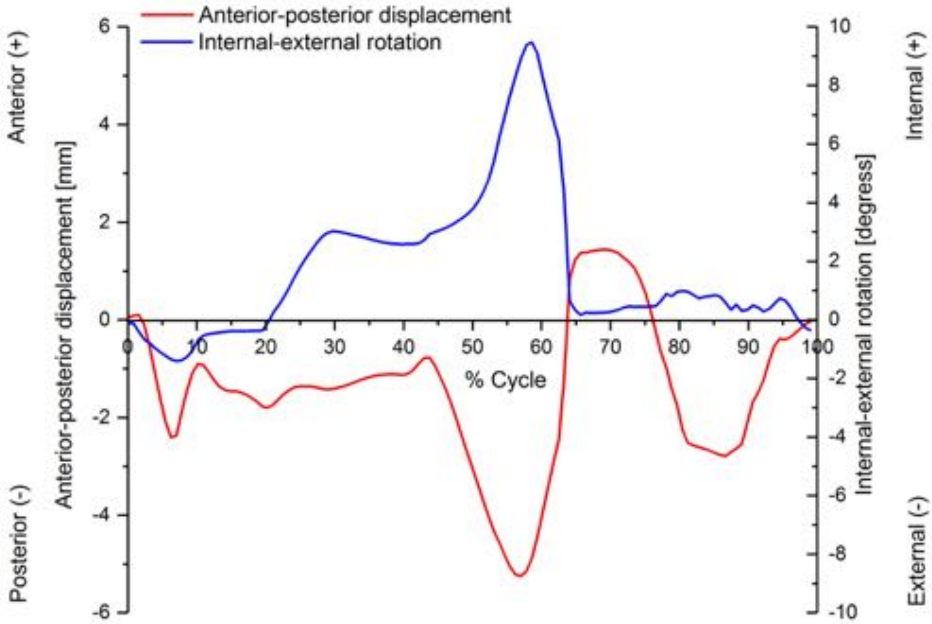

Fig.3: Predicted anterior-posterior and internal-external motions from the force control ISO 2009

Figure 3

#5532

Strain Counter Strain Technique Versus Kinesio Tape in Treating Patients With Myofascial Neck Pain Syndrome

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KEYWORDS: Strain counter strain_ Kinesio tape _ Myofascial pain syndrome

PURPOSE: The purpose of this study was to compare the effects of strain counter strain technique and kinesio tape on Myofascial neck pain syndrome.

BACKGROUNDS/SIGNIFICANCE: Myofascial pain syndrome is one of the most common complaints in clinical practice. Strain Counter Strain technique is non-invasive therapeutic modality for treatment of soft tissue disorders. Kinesio tape is now widely used in management of musculoskeletal injuries.

SUBJECTS: Forty five patients with myofascial neck pain syndrome assigned randomly into: strain counter stain technique group (n=15), kinesio tape group (n=15) and control group (n=15).

METHODS AND MATERIALS: The strain counter stain technique was applied for two weeks (3 sessions/ week-20 minutes per session). kinesio tape was applied for upper Trapezius muscle for two weeks (3days on and one day off). Pressure algometry, Visual analogue scale (VAS) and Neck disability index (NDI) were used to evaluate participants before and after the corresponding interventions.

ANALYSES: Analysis of variance test (ANOVA) was used to determine differences between groups for all measured parameters. Paired t-test was used to compare between the pre- and post-treatment values within groups.

RESULTS: For the 45 study participants (33 women and 12 men; mean age=44.1±7 years) statistical analysis revealed that Subjects in strain counter strain technique and kinesio tape groups experienced significant increase in pressure pain threshold, decrease in neck disability scale and pain level than those in the control group in favor of strain counter strain technique group (p>0.05)

CONCLUSIONS: The results suggest that treatment with strain counter strain technique and kinseo tape were effective however strain counter strain technique was more effective for management of myofascial neck pain syndrome.

FUNDING SOURCE: None

Figures

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

#5533

Effect of Kinesio Tape in Myofascial Pain Syndrome "Randomized Control Trial"

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Backgrounds/significance: Myofascial pain syndrome is one of the most common complaints in clinical practice. Kinesio tape is now widely used in management of musculoskeletal injuries. **Purpose:** The purpose of this study was to compare the effect kinesio Tape technique on neck myofascial pain syndrome of upper trapezius muscle. **Setting:** the study was applied in outpatient clinic of faculty of physical therapy – Cairo University. **Subjects and Method:** Thirty subjects with myofacial pain syndrome (14 males and 16 females), with age ranged from 20 to 50 years old participated in this study. They were assigned into two equal groups each one has 15 subjects: group A kinesio tape for 3 days. Group B (control group) did not receive any physical therapy modality, Patients were randomly assigned into 2 groups using the simple randomization in selection. An almost infinite number of methods can be used to generate a simple randomization sequence based on a random number from the table of numbers of patients and the take odd and even number for equal allocation. Pressure algometry, Neck disability index and Visual analogue scale were used to evaluate participants before and after application kinesio tape technique, and for patients in the control group before and after 3 days. **Results:** Statistical analysis revealed that there was a significant increase in pressure pain threshold, decrease in pain level and function between before and after treatment with kinesio tape group with percentages of (46%, 40%, and 52%). while there was no significant difference in the same measuring variables in than control. Comparison between groups revealed that there was a significant difference between groups and between each groups in pressure pain threshold (PPT) and visual analogue scale (VAS) and neck disability index (NDI), P: probability< 0.05. **Conclusion:** kinesio tape technique is effective method of treatment of neck myofascial pain syndrome. **Key words:** myofascial pain syndrome _ kinesio tape. **Funding:** None. **Ethical approval:** the study was approved by the ethical committee of Cairo University.

Figures

Figure 1

Figure 2

#5522

Proximal Femoral Peri-Prosthetic Fracture in a Cerebral Palsy Patient: Case Report and Literature Review

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Patients with cerebral palsy commonly suffer from pathological fragility fractures as a result of decreased bone strength due to malnutrition and prolonged immobilization. We present a 22-year-old male diagnosed with spastic quadriplegia who presented to our institution with a history of an acute right thigh swelling with no previous history of injury or trauma. Our patient had previously sustained a subtrochanteric femoral fracture that was treated 10 years ago with a Dynamic Compression Plate. Plain radiographs demonstrated a peri-prosthetic femoral shaft fracture at the distal end of the dynamic compression plate[Fig 1]. The patient was treated with an open reduction internal fixation utilizing a reconstruction plate with interfragmentary screw compression[Fig 2]. Historically these injuries were managed conservatively with a long leg or spica cast but this may be obstructive to the frequent nursing care often required. Management of this rare subset of fractures is controversial.

Figures

Figure 1

Figure 2

#6163

Two Type Partial Revision Reverse Shoulder Arthroplasty for Glenoid Notching

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Patients who complained of instability and discomfort in the shoulder of the shoulder due to glenoid notching after right reverse shoulder arthroplasty performed 8 years ago were followed up.

During the follow - up, multiple dislocations occurred and partial revision was performed using glenoid components of other companies.

Other companies' components can also be used when conformity is appropriate.

#5977

Results of Hip and Knee Antibiotic Spacer Use for Two-Stage Revision of Infected THA and TKA

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Introduction:

The current standard of care for late chronic infection is considered to be two-stage revision arthroplasty. This practice requires the removal of the prosthesis, complete débridement, use of an antibiotic-impregnated cement spacer, a course of intravenous antibiotics, and a delayed revision arthroplasty. The purpose of our study is to report the results of a single surgeon series of two-stage revision arthroplasty utilizing antibiotic impregnated spacers.

Methods:

We report the results of a retrospective clinical and radiographic review of 139 hip and knee cases requiring two-stage revision using an antibiotic impregnated spacer. All cases were performed between January 2007 and May 2016. Patients had a minimum of 2-years follow-up.

Results:

Of the 139 cases performed for the reported time frame, 130 (93%) were converted to either a THA or TKA within 3-months of the initial spacer placement. All cases went on to full weigh bearing. Of the 130 conversions cases, there were 2 (1.5%) fractures, 4 (3.1%) revision hip dislocations and 4 (3.1%) revision TKA failures due to aseptic loosening.

Discussion and Conclusion:

Use of antibiotic-impregnated bone-cement spacers is considered to be the standard of care for patients with a chronic infection following total joint arthroplasty of the hip or knee. Antibiotic impregnated spacers provide direct local delivery of antibiotics, preserves patient mobility and facilitates revision arthroplasty. We reported optimum single-surgeon results of two-stage revision arthroplasty for treatment of infected THA and TKA.

#6116

Tibial Insert Micromotion of Revision Fixed-Bearing TKA Protheses

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INTRODUCTION:

In fixed-bearing modular tibial components the backside wear caused by the excess micromotion between the polyethylene insert and the baseplate could result in the release of large amount of wear debris which eventually could cause osteolysis and aseptic loosening of the implant. The purpose of the study was to experimentally evaluate the micromotion between the tibial insert and the tibial baseplate of two revision fixed-bearing TKA prostheses.

METHODS:

Three Attune Revision[R] fixed-bearing tibial inserts with 3 Attune[R] fixed-bearing tibial baseplates and 3 PFC Sigma TC3[R] fixed-bearing tibial inserts with 3 PFC Sigma TC3[R] fixed-bearing tibial baseplates were tested. Heidenhain encoders were utilized to measure the micromotion, and an MTS system was employed to apply the required load to the test construct.

The A/P micromotion test applied a 100 N anterior load to the insert and reversed to a 100 N posterior, and returned to 0 N load position. Two encoders were used to measure the micromotion at the posterior edges of the insert (Figure 1). Micromotion was defined as the total displacement between the minimum and maximum load positions. The greater total displacement of the 2 encoder measurements was used for data analysis.

The M/L micromotion test was identical to the A/P micromotion testing except that the test construct and the load applicator were rotated 90 degrees.

During the rotational micromotion test, the MTS system applied a 1 Nm torque to the insert in the counter-clockwise direction followed by a 6 Nm torque in the clockwise direction, and returned to 0 Nm. A 0 N compressive load was maintained for all test directions. Two encoders were used to measure the micromotion from the posterior edges of the insert (Figure 2). The greater total displacement of the 2 encoder measurements was used to calculate the rotational angle. The A/P and M/L distances from the encoder probe's point of contact to the insert rotational center were measured, and they were employed to convert the linear micromotion measured by the encoders to the rotational angle based on a derived equation.

The resultant micromotion *R* was calculated using the measured A/P and M/L micromotion: $R=SQRT(AP^2 + ML^2)$.

RESULTS:

It was demonstrated that the micromotion of the Attune Revision[R] fixed-bearing tibial implant was significantly less than that of the PFC Sigma[R] TC3 fixed-bearing tibial implant in A/P (p=0.038) and rotational (p=0.013) directions. The M/L (p=0.053) and resultant (p=0.052) micromotion were close to but not significantly different (Table 1).

Table 1

Implant	A/P (µm)	M/L (µm)	R (µm)	Rot (deg)
PFC Sigma TC3	32 ± 8	111 ± 39	115 ± 39	0.62 ± 0.11
Attune Revision	10 ± 1	17 ± 4	20 ± 3	0.07 ± 0.01

DISCUSSION:

The Attune Revision[R] fixed-bearing tibial insert has the same advanced locking mechanism and smooth surface finish as the Attune[R] fixed-bearing tibial insert. Along with the central metal reinforcement pin engaged with the tibial baseplate, the micromotion is substantially reduced.

Figures

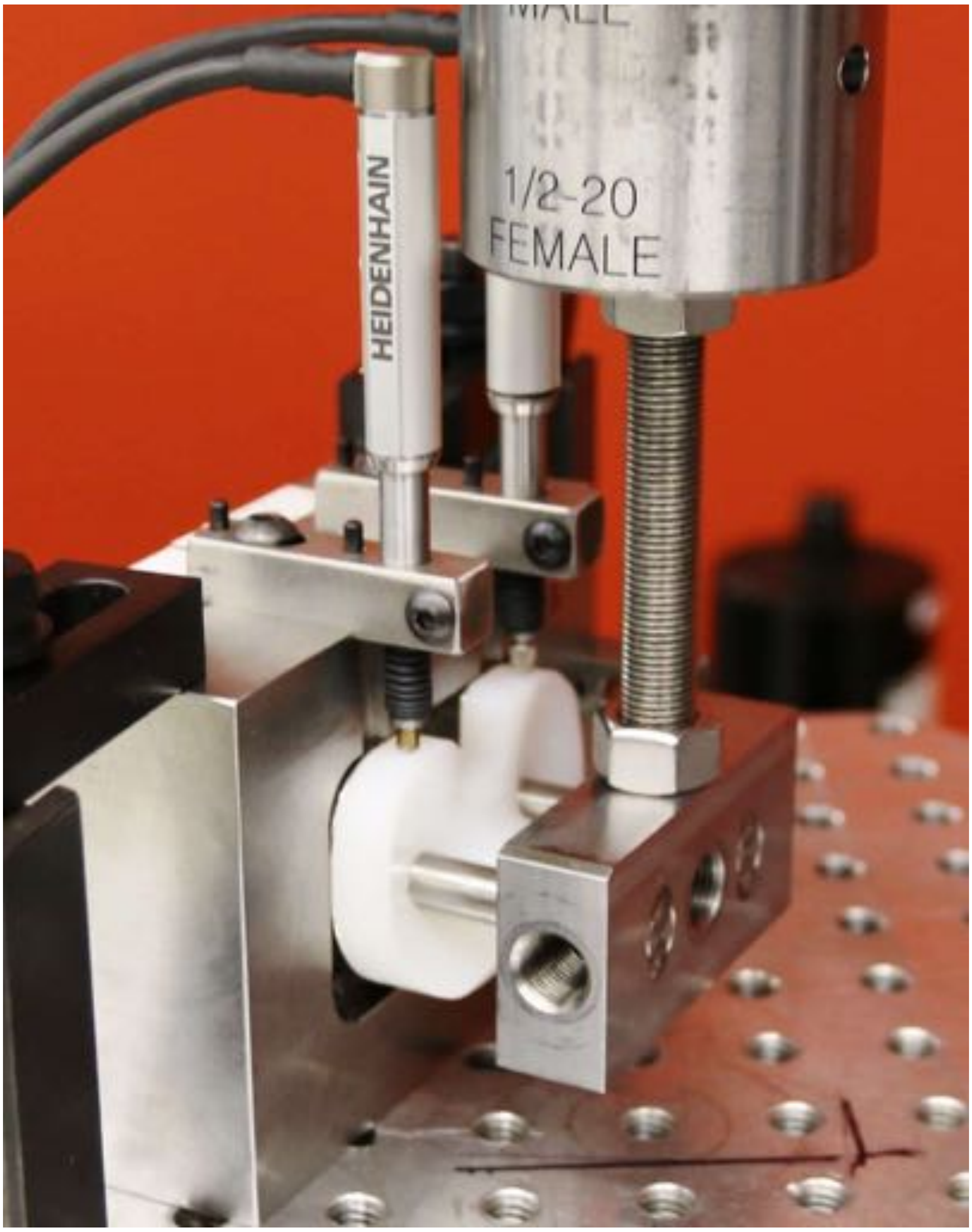

Figure 1

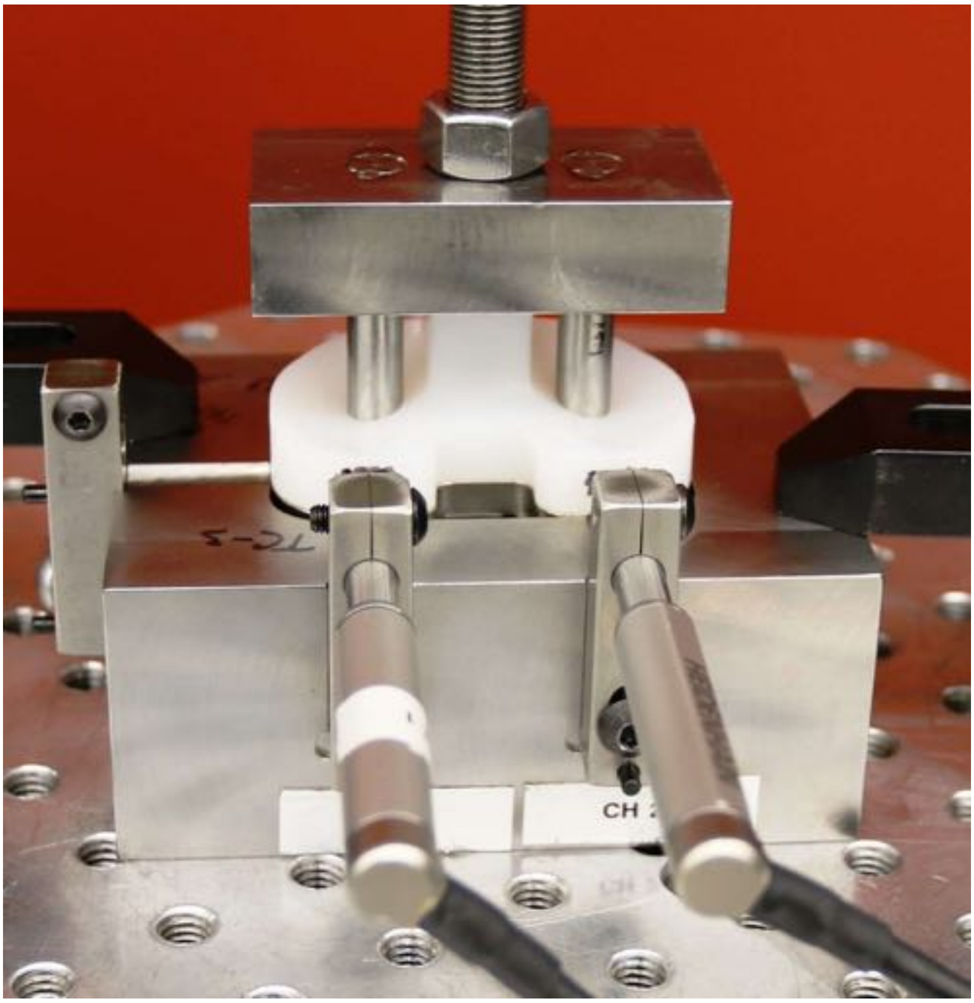

Figure 2

#6012

Short-Term Outcomes of the Muscle-Sparing Anterolateral Versus Direct Lateral Approach to Primary Total Hip Arthroplasty

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Background:

Although total hip arthroplasty (THA) is considered one of the most successful orthopaedic procedures, it is not without its share of complications. As such, finding the optimal surgical approach has become an area of particular interest. In this study, we compare: 1) pain intensity; 2) opioid consumption; 3) lengths of stay (LOS); 4) complication rates; 5) discharge destination; and 6) ambulatory function between patients who underwent THA via the supine muscle-sparing anterolateral (MS-ALA) and conventional direct lateral (DLA) approaches.

Methods:

A retrospective analysis was conducted on 220 consecutive patients who underwent primary THA for hip osteoarthritis using the supine MS-ALA (n=101) or DLA (n=119) between January 1, 2014 and December 31, 2016 **(Table 1)**. Primary outcomes included postoperative pain intensity, opioid consumption, LOS, discharge destination, complications, additional procedures, and time to independent ambulation.

Results:

We demonstrated significantly lower opioid consumption on postoperative days (POD) 1 and 2 (mean differences, -32.0 and -28.4 mg **(Table 2)**, respectively; p ≤0.001 for both) and decreased pain intensity during the second 24 hours of the inpatient hospital stay (mean difference, -22.0; p<0.001) in patients receiving the MS-ALA. Relative to the DLA cohort, patients in the MS-ALA cohort were 2.04 times more likely to be discharged to home (p=0.028) **(Table 3)** and 1.91 times less likely to experience postoperative abductor insufficiency (p=0.039).

Conclusion:

The present study is the first to compare postoperative outcomes, particularly pain intensity and opioid consumption, between patients receiving the supine MS-ALA and DLA to primary THA. Patients that underwent the MS-ALA experienced decreased pain intensity and consumed less opioids in the immediate postoperative period. Furthermore, patients had a higher likelihood of being discharged home, and lower risk for abductor insufficiency in they underwent MS-ALA. Future directions should investigate the effect of surgical approach on quality and cost of care, involve a larger sample size to detect rarer complications, and involve longer-term follow-up.

Figures

Table 1. Demographic information.

	Anterolateral	Direct Lateral	p-value
Number in final cohort	101	119	
Gender, female	47 (46.5%)	65 (54.6%)	0.232
Age, mean (S.D.)	64.0 (10.2)	62.4 (10.8)	0.274
Race:			
Caucasian	63 (62.4%)	59 (49.6%)	
Black or African-American	35 (34.7%)	60 (50.4%)	
Other	3 (3.0%)	0 (0.0%)	0.016
BMI, mean (S.D.)	27.5 (1.2)	32.8 (1.2)	<0.001
ASA:			
1	2 (2.0%)	3 (2.5%)	
2	68 (67.3%)	54 (45.4%)	
3	30 (29.7%)	59 (49.6%)	
4	1 (1.0%)	3 (2.5%)	0.013
Anesthesia type:			
General	24 (23.8%)	40 (33.6%)	
General + Spinal	3 (3.0%)	4 (3.4%)	
Spinal + MAC	74 (73.3%)	75 (63.0%)	0.260

S.D.= standard deviation

Figure 1

Table 2. Repeated-measures ANOVA comparing postoperative opioid consumption and pain intensity.

Dependent Variable	Parameter	Mean MME difference	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Total MME Opioid Consumption, POD0	Anterolateral	-8.352	0.294	-24.016	7.311
	Direct Lateral[a]	0[a]			
Total MME Opioid Consumption, POD1	Anterolateral	-32.000	0.001	-50.802	-13.199
	Direct Lateral[a]	0[a]			
Total MME Opioid Consumption, POD2	Anterolateral	-28.417	<0.001	-43.698	-13.137
	Direct Lateral[a]	0[a]			
Pain Intensity (AUC), 24 hrs	Anterolateral	-7.341	0.112	-16.406	1.723
	Direct Lateral[a]	0[a]			
Pain Intensity (AUC), 48 hrs	Anterolateral	-22.017	<0.001	-33.661	-10.373
	Direct Lateral[a]	0[a]			

[a]Reference

Figure 2

Table 3. Regression analysis comparing outcomes, with direct lateral approach as reference.

Dependent Variable	Significance	Adjusted Odds Ratio[a]	95% C.I. (Lower)	95% C.I. (Upper)
Discharge to home	0.028	2.036	1.078	3.846
Add'l procedures needed	0.820	0.799	0.160	3.986
Any medical complication	0.383	1.736	0.502	6.002
Abductor weakness	0.039	1.905	1.032	3.521
Hematoma/seroma formation	0.064	4.743	0.911	24.7
Any medical or surgical complication (excluding abductor weakness)	0.673	1.186	0.537	2.619

[a]Adjusted for BMI and ASA.
C.I. = confidence interval

Figure 3

Use of New Interactive Patient-Provider Software Improves Patient Satisfaction and Outcomes - a Retrospective Single-Center Study

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Background:

While a number of studies have explored patient- and provider-related factors contributing to quality of care, few studies have explored the role of technology in improving quality and optimizing patient-provider communication. This study explores the use of an interactive patient-provider software platform (IPSP) at a single institution. Specifically, we compared: 1) patient satisfaction scores; 2) complication rates; and 3) readmission rates before and after the use of IPSP on patients undergoing total hip (THA) and knee arthroplasty (TKA).

Methods:

A retrospective review was performed on all THA and TKA patients who completed a Press Ganey (PG) survey at a single institution between the years 2014 and 2017. Primary outcomes included PG patient satisfaction scores, and 90-day complication and readmission rates. Mann-Whitney-U testing and chi-squared analyses were conducted to assess continuous and categorical variables, respectively.

Results:

Analysis revealed an improvement in median CG CAHPS (89 vs. 97; $p < 0.05$)**(Table 1)** and HCAHPS scores (9 vs. 10; $p<0.05$) between pre-IPSP and post-IPSP. There was a decrease in 90-day complication rates (17.4 vs. 14.5%; p=0.016), but no decrease in readmission rates (0.30 vs. 0.18%, p=0.322) between the two time points.

Conclusions:

The use of IPSP proved instrumental in improving patient satisfaction and lowering 90-day complication rates at a single institution. The implementation of IPSP may prove beneficial to arthroplasty surgeons and healthcare institutions alike seeking to optimize the quality of care. Larger multi-center studies are necessary in order to validate the results of the present study.

Figures

Table 1. Comparison of pre-and post-IPSP patient satisfaction scores, readmission and complication rates.

Variable	Pre-IPSP	Post-IPSP	P-value
Mean Overall CGAHPS score	89 (range=69 to 100)	97 (range=75 to 100)	<0.05
Median Overall HCAHPS score	9 (range=0 to 10)	10 (range=0 to 10)	<0.05
Readmission rates	0.30%	0.18%	0.322
Complication rates	17.40%	14.50%	0.016

Figure 1

#6018

Short-Term Outcomes for Total Knee Arthroplasty Patients With Active Extension Lag

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Introduction:

Despite the success of total knee arthroplasty, quadriceps strength can fail to recover. Active extension lag (Q-lag) is a function of quadriceps weakness, whereby patients demonstrate normal range of passive motion with limited active extension. Few studies have evaluated the outcomes of post-total knee arthroplasty patients with Q-lag. Thus, this study aims to compare 1) pain scores; and 2) rates of readmission to physical therapy in total knee arthroplasty patients with Q-lag of ≥15 degrees to patients without Q-lag.

Methods:

A retrospective review of primary total knee arthroplasty patients between 2013 and 2015 was performed. A total of 150 patients (mean age 63 years) **(Table 1)** with a mean follow-up of 32.7 months were analyzed**.** All patients received an evidence-based protocol for physical therapy at our institution. An independent samples t-test and chi-square analysis was conducted to assess the continuous and categorical variables, respectively.

Results:

Fifty-one patients had Q-lag ≥15 degrees and 97 patients had Q-lag <15 degrees at final follow up **(Table 2)**. Analysis of mean pain scores between the groups demonstrated a significant difference in mean pain scores (3.9 vs. 1.9; p=0.043) **(Table 2)**. Chi-square analysis demonstrated no significant difference in rates of PT readmission between patients who presented with Q-lag, and patients without Q-lag [23.5% vs. 13.4%; p=0.118].

Conclusion:

There was no significant difference in readmission rates; however, patients with Q-lag experienced a significantly higher pain level. Further analysis on the effect of Q-lag on functional outcomes and ADL is needed.

Figures

Table 1. Patient Demographics

Number of patients	148
Age	63.0 years (50 to 85)
BMI	33.9 (20.3 to 66.8)
Women	112 (74.7%)
Follow-up	32.7 months (18 months to 47 months)

Figure 1

Table 2. Group characteristics

	Q-lag ≥15 degrees	**Q-lag <15 degrees**	**p-value**
	N=51	N=97	
Age	62.67 (38 to 84)	63.37 (40 to 88)	0.579
BMI (kg/m^2)	32.86	33.21	0.915
Women	37 (72.5%)	74 (76.3%)	0.618
Pre-operative active Range-of-motion	107.5 (55 to 130)	109.8 (80 to 135)	0.321
Pre-operative passive Range-of-motion	114.1 (70 to 130)	117.6 (95 to 145)	0.046
Q lag at discharge	17.1 (15 to 30 degrees)	5.7 (0 to 10 degrees)	<0.001

Figure 2

Table 3. Readmission rates and pain scores for patients with and without Q-lag at latest follow-up

	Q-lag ≥15 degrees	**Q-lag <15 degrees**	**p-value**
Mean VAS Score[a]	1.9 (1 to 6)	3.9 (1 to 6)	0.043
Rates of Readmission	12 (23.5%)	13 (13.4%)	0.118

[a] Visual Analog Scale

Figure 3

#5897

Cement-Less vs. Cemented Fixation in Total Knee Arthroplasty: Usage, Costs, and Complications During the Inpatient Period

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Introduction:

Cemented fixation has been the gold standard in total knee arthroplasty (TKA). However, with younger and more active patients requiring TKA, cement-less (press-fit) fixation has sparked renewed interest. Therefore, we investigated differences in: 1) patient demographics; 2) inpatient costs; 3) short-term complications; and 4) discharge disposition between patients who underwent TKA with cemented and cement-less fixation.

Methods:

The National Inpatient Sample (NIS) database was queried for TKA patients with cement or cement-less fixation between October 1 and December 31 of 2015 **(see Figure 1)**. Primary outcomes of interest included complications, lengths of stay (LOS), discharge disposition, and inpatient costs. Student's t-test and chi-square analysis were used to assess continuous and categorical data, respectively. Multivariable analysis evaluated the effects of fixation type on the continuous and categorical dependent variables.

Results:

Patients with cement-less fixation were younger (63.5 vs. 65.9 years), male (47.4% vs. 40.3%), Black (10.7% vs. 7.7%), from the Northeast census region (29.1% vs. 17.1%), and under private insurance (49.2 vs. 40.3%; p<0.001 for all). Cement-less fixation involved higher inpatient hospital costs ($16,888 vs. 17,357) **(Table 1)** and charges ($64,190 vs. 67,366; p<0.001 for both), lower mean LOS (2.71 vs. 2.63 days; p<0.001), and higher odds of being discharged to home (OR=1.99; p=0.002) **(Table 2)**.

Conclusion:

This study revisited the outcomes of TKA with cement-less fixation, and demonstrated lower inpatient charges and costs, shorter mean LOS, and higher odds of being discharged home. Future studies should investigate patient outcomes and complications past the inpatient period, evaluate long-term survivorship and failure rates, and implement a prospective study design.

Figures

Table 1. Comparisons for differences in costs, charges and length of stay after adjusting for differences in patient and hospital characteristics

	Cemented	Cement-less	p-value
Mean charges (standard error)	64,190.12 (6,041.335)	67,365.53(6,058.14)	**<0.001**
Mean costs (standard error)	16,887.92 (1,204.761)	17,357.18 (1,208.66)	**<0.001**
Mean length of stay (standard error)	2.71 (0.14)	2.63 (0.14)	**<0.001**

Figure 1

Table 2. Model[a] assessment for association between fixation type, adverse events, and discharge disposition.

	Odds Ratio[b]	p-value	Confidence Intervals
Acute renal failure	0.83	0.088	0.68 to 1.03
Urinary tract infection	0.99	0.898	0.83 to 1.17
Pulmonary Embolism	1.25	0.492	0.66 to 2.34
Superficial Surgical site infection	2.31	0.999	-5.05 to 10.68
Post-operative pneumonia	2.27	0.999	-5.01 to 10.31
Discharge home	1.99	**0.002**	1.29 to 3.08

[a] There were no ICD-10 identifiable cases of deep infection, sepsis, shock, wound dehiscence, post-procedural cardiac insufficiency, cerebrovascular accident, and peroneal nerve injury in the database during this time period

[b] Reference= Cemented TKA

Figure 2

Figure 1. Exclusion criteria

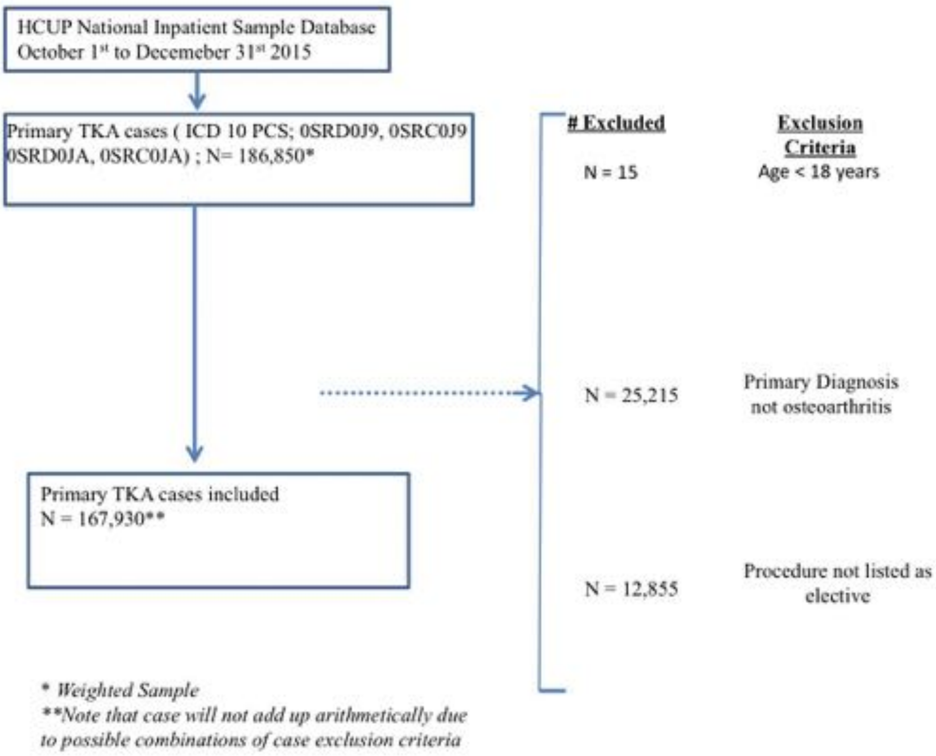

Figure 3

#6161

Reverse Shoulder Arthoplasty for Cuff Tear Arthropathy in Korean Elderly Patients

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Introduction : To evaluate the results of retrograde shoulder arthroplasty in elderly patients with shoulder arthropathy.

Method :

Twenty - one patients who underwent shoulder arthroplasty for shoulder arthropathy between 2010 and 2014 and were followed up for more than 60 months were included in this study. The mean age was 67.5 (63 ~ 82) years old. The mean duration of symptom was 23.4 (7 ~ 120) months. Clinical results were evaluated before and after surgery and VAS, ROM, constant, KSS and UCLA scores were compared. The preoperative and postoperative radiographs showed complications such as lower shoulder collision and relaxation, dislocation and fracture. At least 60 months postoperatively and up to 100 months follow up

Results :

Clinical outcomes were VAS 7.85 before surgery and 2.5 postoperatively. The constant score was 26.15 preoperatively, and the mean follow-up time was 4.8 years. The KSS score improved from 31.2 to 70.7 postoperatively, and the UCLA score improved from 8.9 to 25.1.

Conclusions :

reverse shoulder arthroplasty is a good treatment modality for patients with shoulder arthropathy with symptoms such as pseudoparalysis.

#6094

The Analysis of the Contact Area of the Stem in Total Hip Arthroplasty

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The Analysis of the Contact Area of the Stem in Total Hip Arthroplasty

#5695

New Level for Higher Constraint in Primary Total Knee Replacement

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INTRODUCTION:

In gross deformity and challenging primary Total Knee Replacement (TKA) sometimes the surgeon is forced to use constrained condylar knee (CCK) in order to get knee stability. There are multiple disadvantages of using CCK in primary TKR . We had to revise three cases from primary to revision CCK due to instability in addition removing the primary implant from the patient to use CCK which made the procedure such lengthy with extensive bone loss . We have started using this Constrained posterior stabilizer polyethylene (CPS) in the primary TKR to offer more stability in those patients . Surprisingly CPS has enabled us to avoid the usage of the CCK implant throughout the last 30 months . the purpose of this paper is to give an option for grossly deformed knee without using CCK implant .

METHODS:

In our center we were forced to use CCK implant in over 20 cases annually during gross deformities in our population bases out of 800 TKR . CPS can be locked into a regular persona system which we are using daily, and it offers more stability for valgus stress .We have used CPS for 47 cases with follow-up minimum 30 months in the following indications:Iatrogenic rupture of medial collateral ligament (MCL), Valgus deformity, Varus deformity over 40 degrees . The decision to use the CPS was mainly intra-operative and almost happened after cementing the component where there is medial opening more than 2 mm especially after extensive release and instability in mid flexion . The usage of CPS has enabled us not to use the CCK and it gives great advantage on the long run especially the young patient .

RESULTS:

Post op knee score was similar as compared to match group of Asian size and they were all happy with their outcome . In some cases we have used CPS only on one side during simultaneous bilateral TKR and the patient was unable to tell the difference between the two knees .

DISCUSSION AND CONCLUSION:

We believe that CPS is quite helpful alternative to use in gross deformity and unstable TKR especially in those cases where the implant has already been cemented and the instability was already appreciated post implant cementing . We highly recommend having CPS spacer on shelf especially with fact that such spacer doesn’t need any recut and can be locked to routine tibia implant .

The Length Pattern Assessment of ACL Small Bundles by Using the Biometric Image Matching Technique

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Introduction) Preservation of anterior cruciate ligament (ACL) has the potential to improve postoperative performance in total knee arthroplasty (TKA). ACL is constituted of multiple fascicles, and the multi small bundle structure serves to lead knee motion and stability. Therefore, it is important to understand the length change pattern and function of each small bundle during knee motion. The purpose of this study is to assess the length of each small bundle between femoral and tibial footprint during squat motion in normal knees under normal loading condition using the biometric image matching technique and to investigate the length pattern throughout of range of motion. Additionally, we estimated the tension pattern of the small bundles based on the length patterns.

Methods) The subjects were six healthy knees. The movement studied was a squat motion from full knee extension to a deep flexion. The images used for matching were created as previously reported by our group; we were based on three-dimensional bone models obtained by CT, and matching was accomplished by correlation of images obtained by flat panel equipment. When defining the femoral and tibial footprint, we referred to anatomic study of the normal ACL which revealed the positional relationship between the tibial and femoral attachments of small bundles (hara et al; Am J Sports Med 2009). We divided the ACL into 20 small bundles and defined the femoral footprint using Bernard's quadrant method and tibial footprint was defined by the Amis and Jakob line in the AP direction and by the quadrant method in the ML direction.

Results) The length change of AM position throughout ROM is less smaller than that of PL position. The length pattern of high noon position showed isometric changes. The length pattern of low and deep position showed a longer length pattern in the extended position. In addition, small bundles were existed which showed a longer length pattern in the mid flexion positon and the deep flexion position. It is possible to estimate the tension pattern of each bundle based on the length patterns. From these results, defining the position in the lower direction of ACL femoral footprint leads to stronger tension during extension, the higher and shallower direction leads to isometric during flexion, whereas the deeper direction leads to laxity during flexion.

Discussion) In the present study, we evaluated the length of 20 small bundles accompanying changes in footprint under normal load conditions. The present study showed a slight difference in the position of each small bundle creates each tension pattern and that each ACL small bundles has efficient and complementary roles.

#5892

Characterizing Edge-Wear in UHMWPE Acetabular Cups

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Edge loading occurs when the contact patch between the head and cup extends over the cup rim. There are currently two explanations for this; either there is a loss of entrainment of the synovial fluid which results in a breakdown of the lubricating film [1] or, the increase in wear is a result of a large local increase in contact pressure – as an outcome of the edge loading – consequently reducing film thickness at the rim [1].

Edge loading causes an increase in the wear of implants leading to the failure and revision of these devices [2]. Investigations into edge wear, its effect on osteolysis and failure of hip implants has been very limited for UHMWPE cups. Previous studies conducted on edge wear focus on ceramic-on-ceramic/metal-on-metal bearing surfaces [3] with various other studies focusing on in-vitro simulation with the use of gravimetric measurement to measure wear.

The present contribution aims to demonstrate a novel method to characterise and quantify edge wear in UHMWPE cups using both a roundness measurement machine and a coordinate measurement machine to measure the surface pre-/post-wear. The cups will undergo simulated wear, and analysis will be conducted to quantify linear penetration, volume and creep; with this data then compared to the measured gravimetric results.

Though limited by measurement capabilities the development of a method for edge wear characterisation will allow for wear measurement beyond the edge, removing the limitations of previous methods that focused only on the bearing surface.

1. Underwood, R.J., et al., *Edge loading in metal-on-metal hips: low clearance is a new risk factor.* Proceedings of the Institution of Mechanical Engineers. Part H, Journal of Engineering in Medicine, 2012. **226**(3): p. 217-226.

2. Hussain, A., et al., *Edge Loading of Retrieved MoM Resurfacing Acetabular Cups.* Orthopaedic Research Society, 2011.

3. Kapadia, D., et al., *Method for volumetric assessment of edge-wear in ceramic-on-ceramic acetabular liners.* Wear, 2017. **376-377**: p. 236-242.

#5679

Investigate Risk Factors Related to Clinical Results After Total Hip Arthroplasty in Rheumatoid Arthritis Patients

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[Introduction]

In rheumatoid arthritis (RA) patients, joint replacement surgery for hip or knee is effective for reducing severe pain and ameliorating functional impairment. However, clinical outcomes of total hip arthroplasty (THA) for RA are reportedly inferior to osteoarthritis of the hip in terms of walking ability and activity of daily living, and the factors that contribute to these outcomes are not clear. We hypothesized that preoperative condition of RA might influence postoperative lower limb function after total hip arthroplasty in RA patients. In this study, we examined pre- and post-operative factors associated with the modified Harris Hip Score (mHHS).

[Methods]

Fifty-one joints in 48 RA patients afterTHA were studied retrospectively. All patients were women with a mean age of 66.6±7.7 years at the time of surgery. The mean disease duration of RA was 13.89±8.72 years. The correlation between pre-operative RA activities (Disease Activity Score in 28 joints-C reactive protein: DAS28-CRP and CRP) and mHHS at one year after THA were examined. Furthermore, pre- and post-operative mHHS values were compared between patients with other affected joints (AJ group) and those with no affected joints (NJ group) in the lower limbs.

[Results]

The mean mHHS improved to 73.5 points postoperatively from 36.4 points preoperatively. Pre-operative DAS28-CRP and CRP values were negatively correlated with pre- and post-operative mHHS values. Pre-operative mHHS was not significantly different between the AJ and NJ groups; however, post-operative mHHS were 81.7±12.8 and 67.1±14.6 points in the AJ and NJ groups, respectively, with the AJ group exhibiting a significantly lower score compared to the NJ group. Moreover, the gait and activity sub-scores of the mHHS in the AJ group were significantly lower than the NJ group (gait: 13.4±9.6 and 22.0±8.9, respectively; activities: 9.8±2.5 and 11.6±2.2 points, respectively) (Fig. 5B, 5C). Conversely, the pain sub-score of the mHHS was not significantly different between the two groups (37.9±5.1 and 40.7±5.0 points, respectively)

[Discussion]

THA demonstrated good clinical results for rheumatoid arthritis at short term follow up. However pre- and post-operative mHHS values were influenced by pre-operative RA disease activity. Moreover, the presence of additional affected joints in the lower limbs preoperatively resulted in a lower post-operative mHHS. RA patients often have multiple affected joints, unlike in patients with osteoarthritis, which may contribute to a lower mHHS. Comprehensive treatment, including surgery of the other affected joints in the lower limbs, may improve a patient’s post-operative mHHS.

#5661

The Clinical Results After Arthroscopic Rotator Cuff Repair for the Patients of 75 Years and Over

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Introductions

It has been officially reported that the life expectancy in our country is the longest in the world. Thus the requisition of treatment for the elderly has been increasing. The Purpose of this study is to evaluate the clinical result of arthroscopic rotator cuff repair :ARCR for the patients of 75 years and over.

Methods

One hundred twenty shoulders were operated between June 2013 and September 2017.We evaluated one hundred five shoulders followed up for more than 6 months, and underwent MRI 3-6 months after ARCR. The mean age was 67 years(range:38-81).There were 66 male patients(63%).The mean length of time with pain, from the onset of symptoms to the surgery ,was 10 months(range:1-120 months).Trauma history was admitted in 43 shoulders(41%).Of 105 shoulders,14 shoulders of 75 years old or over were assessed in this study.

We evaluated the clinical results with the Japanese Orthopedic Association shoulder score(JOA score) and assessed the cuff integrity using MRI Sugaya's classification. Type 4 and 5 were considered to be re-tear. Preoperative fatty infiltration(supraspinatus muscle) was assessed using MRI Goutallier's classification. Stage 3 and 4 were considered to be fatty degeneration.

Results

The mean preoperative JOA score in over 75 group(57.9 points) was inferior to that of under 75 group(61.1 points) with significant difference($p<0.05$). It was inferior especially in the field of function(Over 75 group:8.0 points, under 75 group:11.3 points).The mean postoperative JOA score in over 75 group(84.7 points) showed no significant difference compared with under 75 group(84.8 points).The overall JOA score improved significantly after ARCR in both group($p<0.01$). Re-tear rate was no significant difference between over 75 group(27.2%) and under 75 group(18.2%).Fatty degeneration was no significant difference between over 75 group(7.7%) and under 75 group(%).

Conclusion

Although the re-tear rate and postoperative JOA score after ARCR for over 75 group and under 75 group were equal, ARCR for the elderly was considered to need to choose adaptively carefully.

#5549

Post Traumatic Ankle and Foot Deformity, Correction by Multiple Osteotomy and Ilizazrov Rings

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Abstract-1

Post traumatic ankle and foot deformity, correction by multiple osteotomy and ilizazrov rings

Abstract-

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Traumatic injuries to the foot and ankle are devastating to the soft tissue coverage, bony architecture, shape and mobility of the foot and ankle. As the foot is formed by the multiple joints between several bony articulations, deforming forces may damage the anatomy of the foot and its mobility.Soft tissue contractures, cavus ,equinus varus and subtalar ,midfoot and fore foot joints are

responsible for the abnormal shape and functional deficiency of the foot and ankle . Simple corrections of soft tissue, may not be very effective in presence of bony deformity at the mid foot talo-navicular joint ,or calcaneo-cuboid joints .correction even if it is done by surgical means,mya recoil in it and recuurance of same or less deformity are always there.

Material and methods-25 cases of posttraumatic ankle and foot deformity at various level including the sub-talar joint ,mid foot ,fore foot and at ankle were operated .Different types of osteotomies for correction of these done ,customized frame application is preferred and regular follow-up was the key of the successful results .Twelve V osteotomy ,nine cases of pantalar osteotomy ,three cases needed Zapaps osteotomy at midfoot , one case there were multiple deformities which required combination of osteotomies .Soft tissue coverage following the osteotomy was not a big issue as there was crowding of the tissues ate the surgical site.

Fixation of the osteotomy was performed with the help of few K-wires ,along with foot rings, foot frame and three ring at the level of leg, to get the correction of length as there were few limbs with shortening which needed correction as well.

Results- Results were excellent as all foot and ankle osteotomies' united at the site of removal of abnormal bones ,length gained and plantigrade foot achieved.

Discussion -Post implant removal follow-up was also non-significant since patient were informed regarding possible results and shortcoming of the procedure ,but all were satisfied due to positive effect of surgery.

Key words-ankle,foot deformity,wedge correction,ilizarov ring fixator

#6146

Posterior Dislocation Following Revision Total Knee Replacement Arthroplasty: A Case Report

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Knee dislocation following total knee replacement arthroplasty is a rare, but serious complication. The incidence of dislocation following primary total knee arthroplasty with posterior stabilized implants ranges from 0.15 to 0.5%, and posterior dislocation after revision total knee arthroplasty is even rarer. Here, we report the case of a 76 year-old male who presented with posterior dislocation after posterior stabilized revision total knee arthroplasty.

#6108

Volume and Cost of Total Joint Replacement at High-Volume Centers in the US

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INTRODUCTION:

Patient demand for hip and knee arthroplasty continues to rise. Information sources providing data on the volume and cost of Medicare total joint arthroplasty by hospital are of use to patients and healthcare professionals. Data have demonstrated that higher volume surgeons are associated with lower cost, morbidity, and mortality. The current study assesses if the same is true for hospitals.

METHODS:

The Limited Data Set (LDS) from the Centers for Medicare and Medicaid (CMS) were used for this study. All elective, DRG 470 Total Hip Arthroplasties (THA) reported by CMS from the first quarter of 2013 through the second quarter of 2016 were included. Volume and part A Medicare payments over a 90-day period for the 20 highest volume hospitals in the US were analyzed. Cost associated with initial hospital stay and post discharge skilled nursing, home health, long term acute care, inpatient rehabilitation facilities, and readmission was aggregated and analyzed. For each episode, demographic information (age, sex, and race), geographic location, and Elixhauser comorbidities were calculated to control for major confounding factors in the regression.

RESULTS:

For the 20 highest volume centers in the US, total joint volume for CMS insured patients varied from 1104 to 5069. Average cost varied from $16,974 to $22,094. For the 20 highest volume cities in the US, total joint volume for CMS insured patients varied from 1,501 to 6,727. Average Medicare part A payment varied from $14,255 to $21,125. Readmission % varied from 3.9% to 8.2%. 90 day mortality varied from 0.0% to 0.57%.

DISCUSSION AND CONCLUSION:

The variation in volume between the top 20 centers in the US varies by more than a factor of 4 with the highest volume hospital having almost twice the volume as the second highest hospital. Part A payments, readmissions, and mortality also varied widely. Within the top 20 hospitals by volume, there does not appear to be a correlation between volume and cost.

Figures

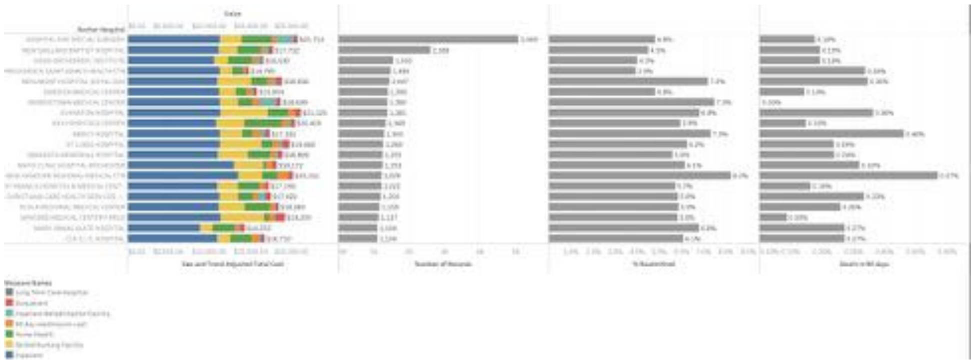

Figure 1

#6104

Trends in Lower Utilization of Inpatient and Post Acute Care in THA

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Payment for value based bundles in Total Hip Arthroplasty (THA), in which surgeons and hospitals accept more responsibility for clinical and financial results, has been generally based on improvement of individual surgeons and hospitals over their own baseline performance. However, there is a general trend toward lower resource utilization for THA in the United States. This study seeks to quantify the background trend of utilization for Medicare cases in the United States.

METHODS:

We performed a retrospective analysis of Centers for Medicare and Medicaid Services (CMS) Limited Data Set (LDS) on all primary elective THAs performed in the United States (except Maryland) between January 2013 and June 2016 on patients insured by Medicare. This represented 409,844 THAs totaling more than USD $7.7 billion in direct CMS expenditures. We adjusted cost to 2013 USD and adjusted for regional variation in spend based on CMS rules. We analyzed CMS Part A payments over 90-day periods, inpatient hospital days, readmissions days, home health visits, and skilled nursing facility days among the years.

RESULTS:

The average duration of inpatient stay has dropped from 2.93 days to 2.40 days, the average days in a skilled nursing facility has dropped from 7.16 to 4.93, the average home health visits has dropped from 9.63 to 8.15, and the average inpatient days from a readmission has dropped from 0.45 to 0.39. Additionally, the average cost of a THA has dropped from $19,497 to $19,033.

DISCUSSION AND CONCLUSION:

There is a trend towards decreased utilization of inpatient and post acute care resources for primary elective THA in the United States. Moreover, overall cost and average days in readmission is decreasing in concert with decreased use of care overall.

Figures

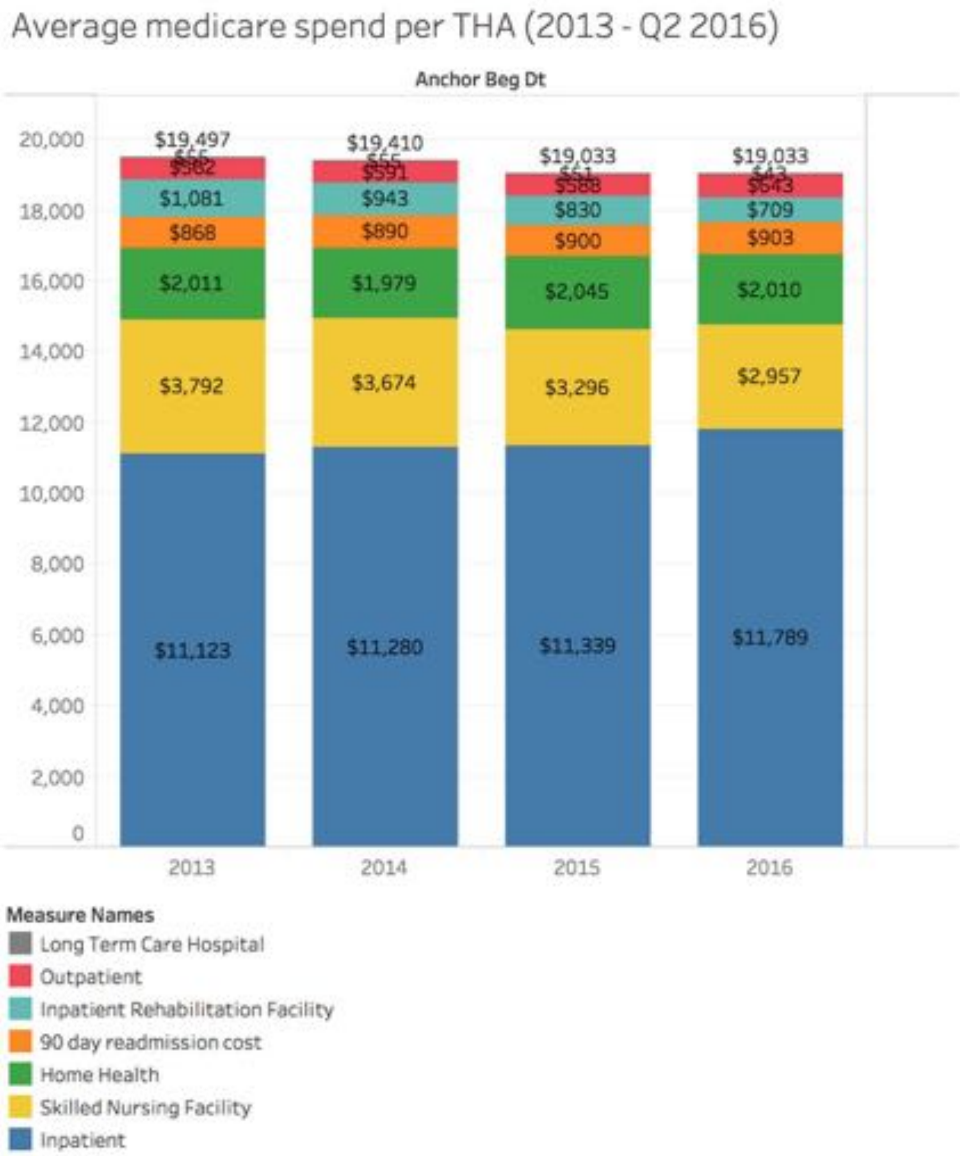

Figure 1

Figure 2

#5652

The Correlation Between Geometry and Pullout Strength of Suture Anchor

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- Instruction

Suture anchor have been widely used in the surgical repair of rotator cuff tears. Pullout strength is affect by characteristics of anchor and determined the success of the operation.

Several studies attempted to correlate type of suture anchors with pullout strength. In the metal screw case, 100% of suture anchors failed by pulling out of the bone. Whereas In the non-metal screw case, it is difficult to found association between pull out strength and anchors. Because in non-metal screw type case, it was occurred anchor or eyelet break fail mode. Furthermore, there is no study about correlation between geometry of anchors and pullout strength.

The purpose of this study was to investigate correlation between geometry of PEEK anchor and pull out strength using FEM.

- Material and Methods.

To simulate, bone model was designed as an isotropic cube model. The Young's modulus and the Poisson's ratio of the cube model were determined as 1,380MPa and 0.3 respectively.

The inserted anchors were made of PEEK and had modeled three types : the dual screw-type, the taper screw-type, the parallel screw-type (Fig.1) In the virtual pullout testing, a tensile load of 500N was applied to the eyelet of anchor to simulate a traction force. The direction of the tensile load was set along the long axis of an inserted anchor. Friction coefficient was set to be 0.0 in the present study.

The distribution of von Mises equivalent stress and the displacement of anchor were compared among three different types of suture anchor.

- Results

Of the three anchors, the hightst von Mises equivalent stress was seen at dual screw. The stress distribution of the taper screw-type and the parallel screw-type was concentrated on eyelet. In the dual screw-type case, a highest stress was shown in eyelet and screw close to the eyelet. (Fig.2)

Comparing the anchor displacement, the taper screw-type anchor had significantly higher pull out strength than other anchors. The amount of tensile load reaching 0.1mm in the taper screw-type, the parallel screw-type and the dual screw-type was 362N, 305N and 240N (Fig.3). The displacement at 500N in the taper screw-type, the parallel screw-type and the dual screw-type was 0.129mm, 0.148mm and 0.191mm. The displacement difference was maximum 35% depends on geometry of anchors.

- Discussion

We found that the geometry of suture anchors and screw type have a significant factor on pull out strength.

Figures

Fig. 1 Anchor Design (a) The dual screw-type anchor (b) The taper screw-type anchor (c) The parallel screw-type anchor

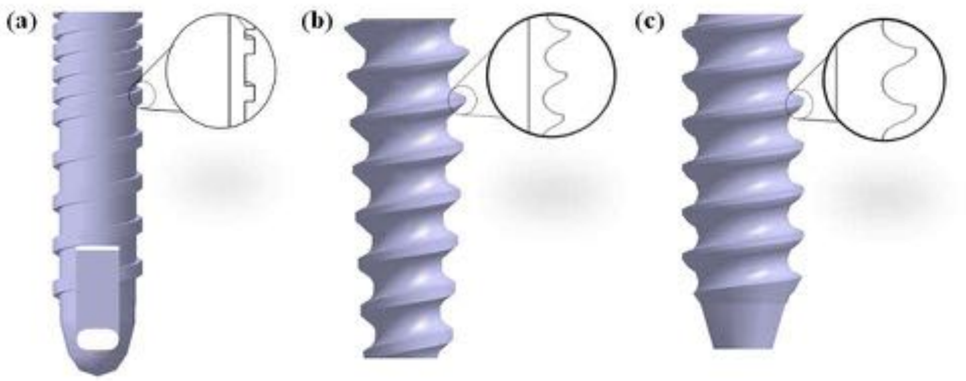

Figure 1

Fig. 2 Distribution of von Mises equivalent stress (a) The dual screw-type anchor (b) The taper screw-type anchor (c) The parallel screw-type anchor

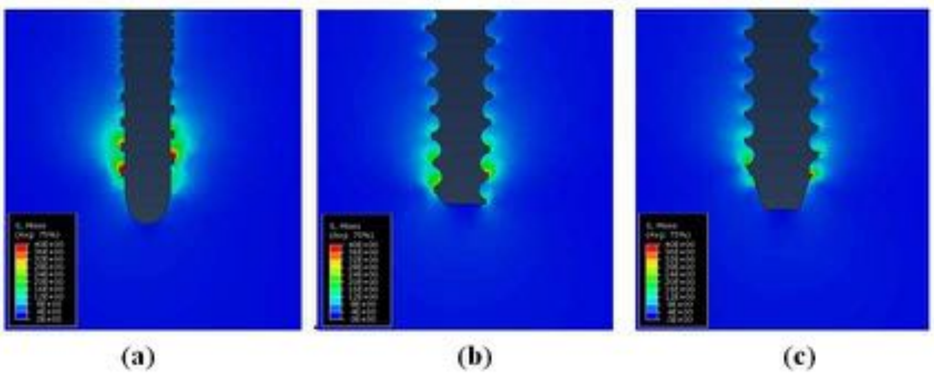

Figure 2

Fig. 3 Comparison displacement of anchors

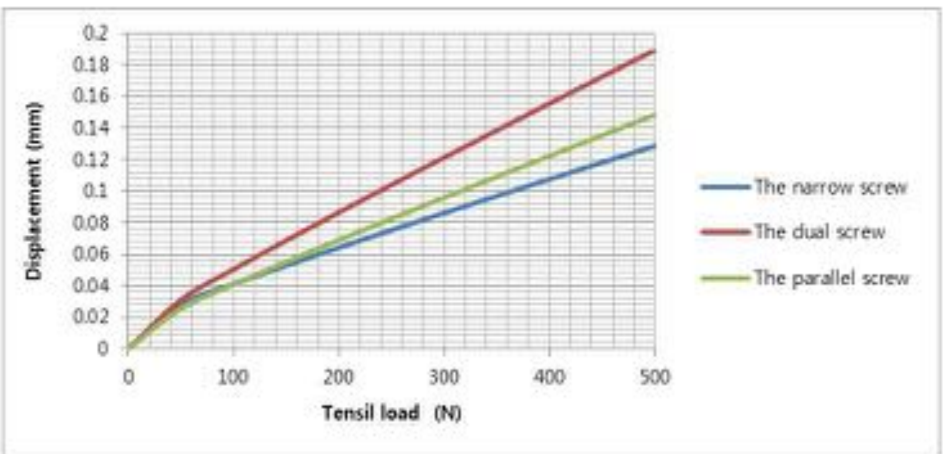

Figure 3

#5719

Stability Analysis of Acetabular Hip Reconstruction Under Different Fixation Modes

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In total hip replacement (THR), it is essential to achieve a primary stability to guarantee good long-term results. When the bone defect is large, acetabular reconstruction is necessary. The majority of these implants are used with cementless fixation that a metal-backing shell is press-fitted into the pelvic bone. After the press-fit with a 1 mm diameter interference, implants can use different fixations, such as three points fixed or two fixed.

We use the finite element softwware to predict the stability of uncemented pressure distribution in different fixed modes. Computational predictions of displacement and micro-motion were closely correlated to clinical findings. The presence of a cancellous defect increased displacement and micro motion between the medial wall of the pelvis and metal acetabular cup. In the same load, boundary conditions and cancellois defect, the modeling predicted that three fixed point is the most stable. Compared to the defect modeling without acetabular renovations, using different fixations promote the stability of cup and pelvis at the same time. Our modeing approach can provide some suggestions for the clinical surgery.

Figures

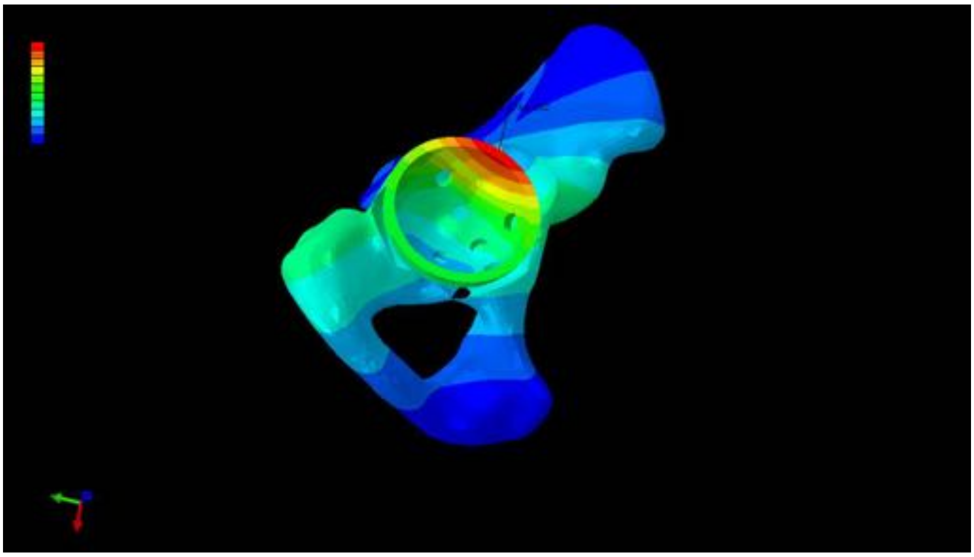

Figure 1

#5518

What Patients Want Out of Their Total Knee Replacement?- an Indian Perspective

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Introduction and Aim : The TKR is one of the most successful operations in orthopedics still a sizable percentage of patients remain dissatisfied Various studies have been conducted to analyze the red flags associated with poor outcome In this study we tried to have insight on what actually patients want out of their TKR operation

Methods : 50 patients were studied by way of patient expectation feedback form The form had various patient related capture points It had a leading question : What are your expectations from TKR?. They were asked to rank or number the 5 most important options in the increasing order of importance

Results : 70% of patients ranked relief of pain as the most important expectation 20% reported improvement in walking as the number one expectation Nearly equal no listed improvement in walking and ease of doing day today activities as the second most important expectation , This was followed by improvement in climbing the stairs and improvement in quality of life Correction of deformity and no pain while getting up from sitting position ranked at the bottom of the list

Conclusion : Despite the hype about the perceived advantage of the high flexion TKR designs about their ability to help the patient to do deep flexion activities like squatting or sitting cross legged, the most important expectations of Indian patients from their TKR are relief of pain and improvement in walking followed by ease of doing day to day activities and improvement in quality of life

#6023

Virtual Reality Simulation of Orthopedic Surgery for Academic Use

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On the path to becoming an orthopedic surgeon one must invest hours of studying and practice before they can perform surgery on a patient. Typically, residents begin their training with textbooks and exams, then practice on cadavers before assisting in real surgeries on live patients. While this process has been effective thus far, the efficacy and efficiency could be improved with the proper changes. Textbooks and exams are an important first step, but are limited to anatomy, history, and procedural steps of a given surgery, and provide little realistic experience in performing a surgery. Cadaveric practice provides great hands-on experience, but cadavers are a limited resource and each type of surgery can only be performed once on a single cadaver. This leads to increased levels of medical waste and residents have limited access to practice their techniques. By the time residents perform surgery on a living patient, they have very limited experience and are highly prone to mistakes and an overall lack of confidence in the operating room. Our proposed solution to this problem is a virtual reality (VR) simulation for orthopedic surgery. VR is a hands-on approach to learning that will reduce medical waste, allow residents unlimited practice, will not require the presence or guidance of an experienced surgeon, and will give residents the experience needed to walk into an operating room confidently, thus reducing the frequency of mistakes made on living patients. Our goal is not to have this system replace any of the current teaching methods, but to be an additional step in the process. The system utilizes the Oculus Rift Virtual Reality System which allows residents to enter a virtual operating room from the viewpoint of the lead surgeon. Residents then use their hands to manipulate tools and repair fractures using the proper reduction and fixation techniques. The current system is loaded with the tools needed to perform pelvic fracture repair, but future versions will allow for the practice of all of the most common fractures and arthroplasties. What sets this VR system apart from other similar systems, is that ours will use 3D replicas of real bones analyzed from MRI and CT scans, not simplified animations. This will give residents the ability to practice a surgery with a specific patient’s exact shape, size, and location of their bones, tendons, and ligaments before making the first incision.

#6055

A Comparative Shopping Guide Compendium for Robot-Assisted Surgical Systems for Lower Extremity Joint Arthroplasties

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Background: With the continual development and introduction of new robotic-assisted navigation surgical systems in total hip and knee arthroplasties (THA/TKA) and unicompartmental knee arthroplasty (UKA), there is an ever-present need for a comparative study of the major systems that are prevalent in these procedures. This comparison entails the evaluation of system specific properties that should be taken into consideration from the relative perspectives of the patient, surgeon, and hospital.

Methods: The purpose of this study is to offer a comparative analysis that presents a shopping guide with currently available data for existing robotic technology in the applied field of adult reconstructive surgery of the lower extremities.

Results: The needs and demands of each party varies. Patients are concerned with the surgeon's role during the procedure (pilot vs. co-pilot), risks of potential harm, time under anesthesia, safety records, recovery time, and preoperative costs. When using these assistive platforms, surgeons must consider several factors that correlate with those of the patient such as preoperative imaging and planning, procedure execution with haptic guidance, how procedure time is affected (Fig. 1), learning curves, and intraoperative verification of bone cuts. With regards to preoperative planning, orthopedic robots work on rigid, bony landscapes that can be surveyed beforehand, as compared to soft tissue surgeries that have a variable surface topography. Some systems accomplish this via CT scans, which provides another element of consideration for the surgeon and patient due to radiation exposure. Lastly, hospitals must evaluate the capital and ancillary costs of each system, contracts that would be made with parent companies, and make sure that the technology has been validated in several case studies before committing to the purchase of any system.

Conclusion: This study provides an updated compendium of available data about the leading robotic systems used in lower extremity joint arthroplasty surgery. The data has been organized to meet the demands of surgeons, patients, hospitals and third-party payors.

Figures

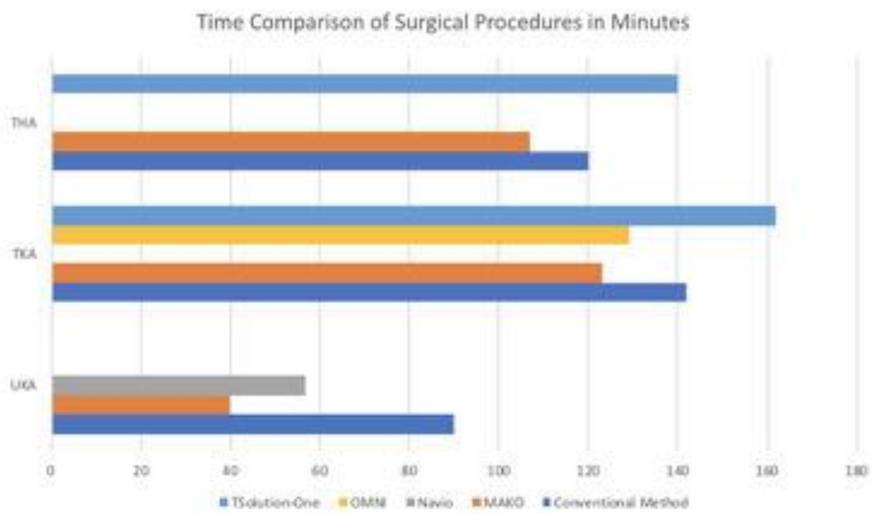

Fig 1. Time comparison of surgical procedure times between conventional by hand method and different robotic platforms for their respective functions.

Figure 1

#5704

Clinical and Radiographic Results of the PFC Sigma TC3- RP Mobile Bearing Prosthesis: A Consecutive Series at 5 Year Follow Up

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Introduction: The PFC Sigma TC3-RP is the modification of the fixed bearing TC3, also known as a constrained condylar knee (CCK), to provide rotational freedom and superior mediolateral stability as the post is more conforming in the medial and lateral planes. The aim of this study is to analyze the short to medium term clinical results of this prosthesis for a primary and revision indications.

Methods: From an institutional review board approved registry, we retrospectively reviewed 50 consecutive primary and revision total knee arthroplasty (TKA) cases with TC3-RP between 2008 and 2015: 14 primary and 36 revision cases. The mean follow-up was 5.1 ± 1.8 years (2 - 7.2) Clinical analysis included WOMAC, Knee Society Score (KSS), patient administered questionnaires (PAQ), satisfaction, and survivorship. Radiographs were assessed for alignment, loosening and osteolysis.

Results: Mean WOMAC, PAQ, and KSS scores were 20 ± 19 (0-68), 26 ± 19.8 (0-69), and 81.4 ± 18.7 (44-100), respectively. The mean ROM was 110° ± 19 (45°-130°). Five cases were revised: four for persistent or recurrent peri-prosthetic infection and one for aseptic loosening. Survivorship for the TC3-RP was 88% for all causes and 100% for mechanical failure. Radiographic analysis revealed no aseptic loosening or evidence of osteolysis.

Conclusions: At mean of 5-year follow-up, TC3-RP has provided excellent clinical and patient recorded outcomes. We believe this is the implant of choice for treating complex primary knee instability, neuropathic joint, and for select revision cases. To our knowledge, this is the first report on primary and revision TC3-RP.

#5699

Total Joint Arthroplasty in Immunocompromised Patients: A Matched Pair Analysis for Co-Morbidities

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Background: The prevalence and demand for total joint arthroplasty (TJA) in patients with Human Immunodeficiency Virus (HIV), Hepatitis B (HBV) and Hepatitis C (HCV), have steadily increased. However, the relationship between these immunocompromising viruses and perioperative complications such as postoperative infection has yet to be fully established.

Methods: 107 TJAs (48 THAs and 59 TKAs) performed in immunocompromised (IC) patients between 2008 and 2014. Patients were matched based on sex, age, BMI, and operation (TKA vs. THA) to patients who were non-immunocompromised (N-IC). A cohort of 66 IC patients were also matched with 66 N-IC based on medical comorbidities to assess for medical co-morbidities that may increase the risk of infection.

Results: The overall complication rate in the IC group and N-IC groups was 20% (22 patients) and 14.6% (16 patients), respectively, which was not statistically significant (p= 0.34). There were no differences between the two groups in the incidence of deep (n=6; 5.5% vs. n=3; 2.7%; p=0.36) or superficial infections (n=4; 2.1% vs. n=1; 0.9%; p=0.50), or re-admissions (n=12; 11% vs. 14; 12.8%; p=0.80). However, there was a significant difference for re-operation (16 versus 6, p = 0.04). When data was adjusted for co-founding factors for complications, matched for co-morbidities, the rate of infection and re-operation were 7.5% and 4.5% in IC and 9% and 6% in N-IC groups, respectively, which were not statistically significant.

Conclusion: Immunocompromised patients were not at a significant increased risk for perioperative complications, postoperative infections or readmissions, but were associated with a higher risk of reoperation.

#5700

Alternative Payment Models in Total Joint Arthroplasty Under the Affordable Care Act

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The original architects of Medicare modeled the payment system on the existing fee-for-service (FFS) structure that historically dominated the health insurance market. Under the FFS paradigm, healthcare expenditures experienced an exponential rise. In response, the managed care and capitation models of healthcare delivery were created. However, changes in Medicare reimbursements along with an increasing volume of orthopaedic procedures, and escalating implant costs put into question the cost-effectiveness of this service line. The success of theacute care episode demonstration project proved the feasibility of value-based care and ushered in a new era of bundled payment initiatives.

Since the passage of the Patient Protection and Affordable Care Act (ACA), healthcare has transitioned from volume-based to quality-based. Under this legislation, Alternative Payment Models (APMs) [Bundled Payments for Care Improvement (BPCI), Comprehensive Care for Joint Replacement (CJR), and Affordable Care Organizations (ACOs)] have been developed to provide stakeholders with reimbursement systems that reward high quality care and cost reduction.

#5906

Fracture Mechanism of Higher PTSA Angle Knee Using FE Simulation

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Salter-Harris (SH) fractures refer to childhood fractures found in the growth plates. These faults may lead to premature closure, which could result in the limb shortening, the angular limb deformity, or joint incongruity. SH type II fracture of the proximal tibia is an athletic-related fracture that follows the soft epiphyseal line and goes across most of the epiphyseal plate and up through the shin bone. This fracture may be induced by differences in the posterior tibial slope angle (PTSA). The aim of this work is to reveal the difference of load-bearing function between the normal knee and the higher PTSA ('easily-injured', 5 degrees) one around the growth plate. Each 3D tibial finite element mesh which was divided into the cortical, cancellous bone and soft epiphyseal plate were constructed from the DICOM data files. Both knee meshes were fixed at 180 mm distal to the joint surface. The 2000N compression to the joint surface, the 1460N tensile loading from patella tendon were applied to the models. FE simulations were performed by using ABAQUS and CalculiX softwares which work on a supercomputer (PRIMERGY CX400, Fujitsu, Japan).

In the FE simulation results, the maximum shear (fracture) strain of normal and easily-injured model is similarly ranged from 0 to 0.3. However, the result of the easily-injured model shows that the fracture strain concentrates at the interface between the soft epiphyseal plate and proximal tibial cortical bone and that the 'hoop-shaped' strain distribution was observed on surface of the epiphyseal plate. Compared to the normal knee model, the epiphyseal plate of higher PTSA model may be subjected to not only tensile force from the patellar tendon but also the larger moment caused by the higher PTSA.

Figures

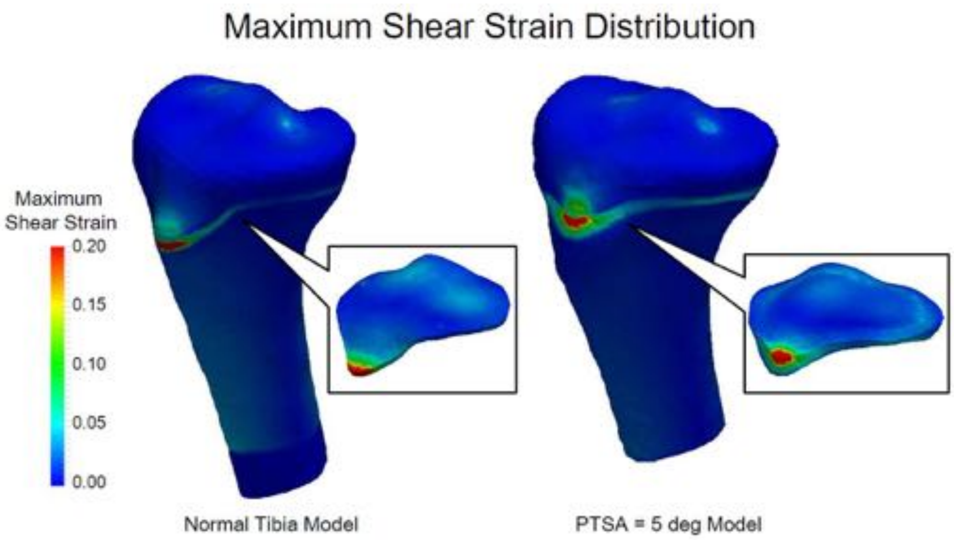

Figure 1

#6142

Evaluation of Lower Score in Patient-Reported Outcomes After Direct Anterior Total Hip Arthroplasty

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Background

There is a growing recognition of the importance of patient-reported outcome measures (PROMs). These measures are used to assess patient satisfaction in the evaluation of outcomes of medical and surgical interventions. This present study aimed to detect predictable factors in the preoperative period that would lead to a lower score on PROMs in the postoperative period in total hip arthroplasty (THA).

Methods

As a PROM, the Japanese Orthopaedic Association Hip-Disease Evaluation Questionnaire (JHEQ) included categories of pain, movement, and mental factors to evaluate outcomes in the preoperative period and 12 months after surgery. All THA procedures were performed using a direct anterior approach(DAA), and all surgical procedures were performed by three surgeons. The study subjects comprised 713 patients who completed the JHEQ in the preoperative period and 12 months after primary THA surgery. In addition to the JHEQ, age, body mass index (BMI), operating time, and bleeding amount were evaluated. Multivariate analysis was used to statistically analyze in numerical variables.

Results

Mean age was 61.7 years old, average BMI was 23.8, average operating time was 42minutes, and average JHEQ score was 20.6 in the preoperative period and 70.8 in 12 months after surgery.Significant difference in age, BMI, operating time and JHEQ score were observed in the preoperative period.

Conclusion

JHEQ was completed by patients in the preoperative period and 12 months after primary THA with DAA. Older age, higher BMI, longer operating time, and low JHEQ score are predictable factors for a low JHEQ score in the preoperative period.

Wear Behavior of the Constrained Hip Systems

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Objective: Constrained liners are used to improve the implant stability for patients with instability rising from dislocations due to inadequate soft tissues. Despite the stability benefits, there are concerns about excessive polyethylene wear and osteolysis due to increase constraint associated with the device. There have been very few studies reporting the wear behavior of the constrained hip system. The objective of the current study is to evaluate and report the wear from the constrained hip system under normal and aggressive test conditions and compare the wear rate to the threshold from osteolysis.

Methods: Hip wear testing performed on 28-day aged Vitamin E Cross-linked Polyethylene VEXPE (blended Vitamin E, 10 MRad, Eto sterilized) acetabular liners with 32 mm metal (CoCr) femoral head bearings. Testing was conducted in two conditions (a) normal conditions where both articulating surfaces are in pristine condition and (b) aggressive-conditions where femoral heads were roughened using a diamond indenter. Each group consisted of a minimum of three bearing couples for wear test, and one bearing pairs for the load or control soaks. Hip wear testing was conducted as per methods outlined in ISO14242-3. Before the start of the test, the surface roughness, diameter, and sphericity of each bearing component (head and liner) measured. Before the start of the test, all the liners soaked in the test lubricant for 48 hours. The soaked acetabular liners were cleaned and weighed after removing from the test lubricant and tested in a 12-station orbital-bearing hip wear test machines in the anatomically oriented position. ISO gait profile with a minimum and maximum force of 300 N and 3000 N respectively was applied to the bearings at 1 Hz. The loading was synchronized with a +/-23 degree biaxial rocking motion. The lubricant used for this testing was 25% bovine serum with 0.2 % sodium azide, 20 mM EDTA and distilled water all maintained at room temperature. The test was interrupted at regular intervals of 0.5 Mc from 0-1Mc and after that for every 1Mc for gravimetric assessment of the bearing wear. Specimen cleaning and wear assessment performed per ASTM F 1714-96 and ISO 14242-2 standards. Lubricant volume and concentration was maintained by the periodic addition of distilled water to compensate for the evaporation of water during the tests.

Results & Discussion: Figure 1 shows the results of the wear testing. VEXPE liners exhibited lower wear than the VEXPE liners under both testing conditions (i.e., normal and aggressive wear conditions). The results from the study demonstrate the wear magnitude that is lower than the threshold required for osteolysis which is reported to be 80 mm^3/Mc (per Oparaugo and colleagues). Also, the bearings appeared to be insensitive to the roughness of the femoral head since bearings exhibited similar wear under normal and aggressive conditions indicating the ability of VEXPE material to withstand aggressive conditions. The results of the testing demonstrate that VEXPE constrained liners will generate lower wear than the threshold for osteolysis and thus safe and durable.

Figures

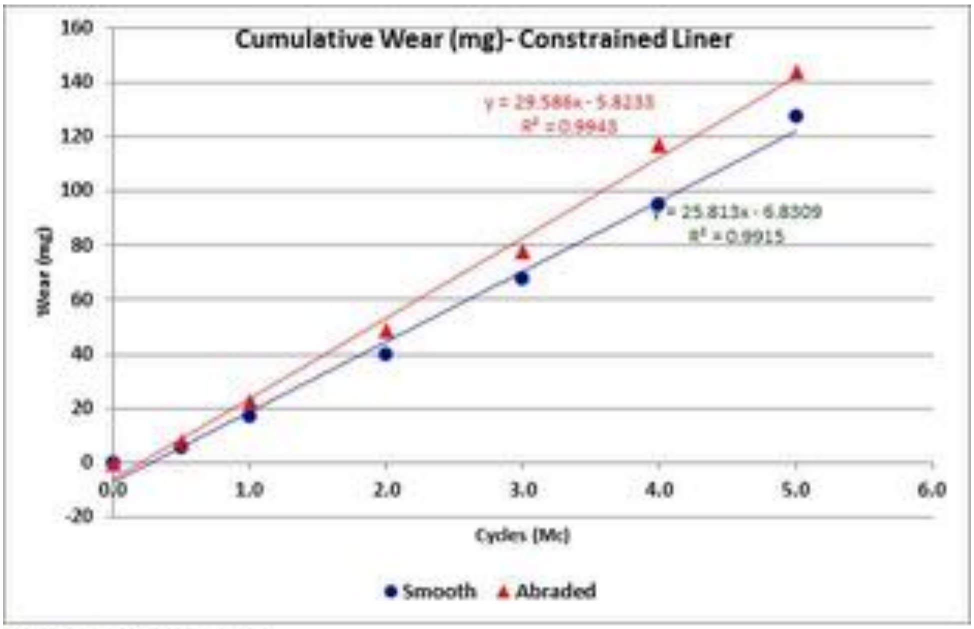

Figure 1: Wear Results

Figure 1

#6021

90-Day Perioperative Complications in Patients Undergoing Anterior Cervical Discectomy and Fusion (ACDF) With and Without Hypothyroidism: A Retrospective Analysis

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INTRODUCTION: Anterior Cervical Discectomy and Fusion (ACDF) is a proposed treatment for patients with cervical radiculopathy. Currently, there is limited literature available on complications in patients undergoing ACDF with concurrent diagnosis of hypothyroidism. The aim of this study was to compare postoperative complication rates, within 90 days, in patients undergoing ACDF with and without hypothyroidism.

METHODS: A retrospective analysis was done using a national provider database was performed. The Medicare database was the insurance provider for our study. Utilizing the International Classification of Disease, ninth revision (ICD-9) codes facilitated in capturing our study group. Our study group was compared to a control group – patients without hypothyroidism undergoing ACDF. Both groups were longitudinally followed for 90 days from their index procedure. Descriptive and statistical analysis of various complications was performed with the programming language R (University of Auckland, New Zealand).

DISCUSSION & RESULTS: Patients with hypothyroidism who underwent ACDF were found to have greater odds and incidence of pulmonary embolism (OR:1.60, 95%CI: 1.07 – 2.40, $p = 0.02$)(.11% vs .07%) cerebrovascular accidents (OR: 1.79, 95%CI: 1.24 – 2.59, $p = 0.0019$)(.14% vs .08%) postoperative hemorrhagic anemia (OR: 2.26, 95%CI: 1.80 – 2.85, $p<0.001$)(.44% vs .19%), thrombocytopenia (OR: 2.89, 95%CI: 1.86 – 4.48, $p < 0.001$)(.14% vs .05%), acute respiratory failure(OR:1.78, 95%CI: 1.28 – 2.47, $p<0.001$)(.18% vs .10%), and urinary tract infection (UTI)(OR: 2.18, 95%CI: 1.96 – 2.43, $p<0.001$)(1.9% vs .88%), compared to patients without hypothyroidism. Readmission rates within 90 days showed that patients with hypothyroidism had greater adjusted relative risk and incidence (aRR) (aRR: 1.31, 95%CI: 1.25 – 1.37, $p < 0.001$) (10% vs 7.7%) of being readmitted to the hospital, compared to the control group.

CONCLUSION: Hypothyroidism increases the risk of various medical complications compared to patients without the condition, when undergoing ACDF. Appropriate counseling and presurgical optimization could potentially prevent many of these complications.

#6167

A Case of Distal Humeral Non-Union Which Acquired Elbow Flexion Defficiency and Ulnar and Median Nerve Symptoms After Total Elbow Arthroplasty

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Excessive shortening of the humerus when performing total elbow arthroplasty can cause several complications. We have surgically treated a case of post-traumatic non-union which was treated with a semi-constrained total elbow prosthesis and acquired elbow flexion defficiency and ulnar and median nerve symptoms.

The case was a 70-year old man who had injured from a fall in 2014, and was diagnosed as distal humeral fracture (AO 13-C1). He underwent open reduction and internal fixation, and two non-union operations without achieving bone union. Semi-constrained total elbow (Nexel Elbow, Zimmer) was performed at another hospital, 40 months after the primary operation. The condyle fragments were removed on placing the humeral component, leaving approximately 2 inches of shortening. The patient visited our hopital one month after the total elbow arthroplasty, complaining of weakness in his elbow and neuralgia of the median and ulnar nerve areas. Active horizontal flexion was 50 degrees, and the strength was equivalent to MMT 1+. Two months after the total elbow arthroplasty, we have performed shortening and re-suturing of the biceps tendon, and neurolysis of the median and ulnar nerves. Due to the excessive shortening of the humerus, the nerves were substancially kinked and compressed due to tethering of the surrounding soft tissues. At five post-operative month, active elbow flexion against gravity is 90 degrees and passive flexion is 130 degrees, and the neuralgia has almost subsided.

Shortening of the humerus must be avoided as much as possible. The Nexel elbow humeral component with a long flange can compensate up to 8 centimetres of bone loss, hence should always be considered for post-traumatic cases with substancial amount of the condyles absent.

#6207

Postoperative Digital Templating in Total Hip Arthroplasty: An Objective Analysis of Practice

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Background:

Pre-operative digital imaging is being widely used for operative planning for total hip arthroplasty. However, analysis of post-operative radiographs remains empirical and prone to inter observer error. Our aim was to undertake digital evaluation of postoperative radiographs to assess the accuracy of implant position.

Methods:

A review of radiographs of 136 consecutive total hip replacements performed by two arthroplasty surgeons in our unit from January to December 2017 was undertaken. There were 41 males and 95 female patients. Mean age was 68.4 years (Range 50 to 84 years). Trauma CAD and Orthoview software on PACS (Fuji Technologies) was used for analysis. Parameters reviewed were limb length, position and offset of femoral stem and acetabular cup theta angle and was undertaken by two observers to eliminate bias.

Results:

Mean postoperative femoral offset was 42.9 mm (Range: 23.5 to 68.5 mm). In comparison, the opposite side femoral offset was 41.7 mm (Range: 20 to 72.5 mm). Mean acetabular cup theta angle was 42.4 degrees (Range: 26-53 degrees). Mean femoral stem alignment was a varus of 0.70 degrees (Range: varus 6 to valgus 7 degrees). Mean preoperative limb length discrepancy was shortening of 3.1 mm (Range: minus 20 to plus 14 mm) and postoperative lengthening of 1.4 mm (Range: minus 15 to plus 21 mm).

Conclusions:

Post-operative digital templating is a useful analytical method for objective evaluation of total hip arthroplasty. It helps to review trends and modify practice accordingly. It can also be used as an appraisal, revalidation, research and teaching tool.

#6203

Bilateral Cement Venogram Following Total Hip Replacements: Excellent Cementation or Excessive Pressurisation?

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Background

The importance of good cementing technique for the long-term survival of cemented femoral components in total hip arthroplasty cannot be overemphasised. However, the surgical dilemma between excellent cementation with adequate pressurisation and excessive pressurisation with attendant risk of embolic events is valid. We are reporting an incidental finding of bilateral cement venogram on post-operative radiographs following uneventful sequential total hip replacements.

Methods

A 66-year old woman underwent an uneventful left total hip replacement in the lateral position via the posterior approach in October 2013, utilising a cemented Exeter femoral component. Cementation was performed utilising standard modern cementing technique. The cement was inserted retrograde with a cement gun and judicious pressurisation. The femoral component was inserted without any intra-operative complications. She proceeded with right cemented total hip replacement with similar technique in January 2017 uneventfully. Postoperative radiographs demonstrated cement venogam after successive total hip replacements.

Results

Our patient made uncomplicated recovery after sequential bilateral total hip replacements. Postoperative radiographs, however, revealed incidental cement venogram after successive total hip replacements. Three years after left total hip replacement, she remained clinically and radiologically satisfactory and there was no radiological evidence of cement migration on the left. Cement venogram has been reported in rare case reports previously. Post operative deep venous thrombosis was noted in one patient. Our patient merely had asymptomatic uncomplicated incidental bilateral cement venogramwith no associated complications.

Conclusions

Bilateral cement venogram seems to be a reflection of excellent cementation of the femoral component rather than an indication of possible attributable associated complication. To our knowledge, bilateral cement venogram after total hip replacements has not been reported todate.

#5896

Effect of Repeat Testing on the Mechanical Behaviour of the Porcine Lumbar Spine

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Back pain is the leading cause of disability worldwide, it affects a tenth of the world population and represents a challenging socio-economic problem. In order to understand the mechanisms contributing to back pain, a substantial body of research on the biomechanical behaviour of the spine has been undertaken. Many of the studies aiming to compare the effect of different test parameters on the mechanical properties of the spine involve repeated testing of the same specimen. However, retesting a specimen can result in fluid exuding from the intervertebral disc (IVD), which may cause a change in properties during testing. The aim of this study was to investigate the change in stiffness of the IVD when specimens were subjected to multiple testing repetitions.

A six degrees-of-freedom electro-mechanical custom-built spine simulator capable of performing both the stiffness and flexibility testing protocols, was used to test sixteen porcine lumbar functional spinal units, at a frequency of 0.1 Hz under 400 N preload. During testing, specimens were wrapped in wet gauze and cling film to minimise moisture loss. Half of the specimens were tested using the stiffness protocol and the other half using the flexibility protocol, at equivalent loading amplitudes. Specimens were subjected to five identical repeat tests, with a 30 minute equilibration period between each test.

An increase in the main diagonal stiffness matrix terms was recorded for all axes. In comparing median stiffnesses produced from the stiffness and flexibility protocols, the lateral bending stiffness increased by 253% and 66% after five cycles, in the case of flexion-extension the increase was 44% and 40%. For all other axes, retesting a specimen resulted in an increase of the median stiffness of less than 15%. Overall the increase in stiffness was largest between the first and second test, and it was found that the stiffness protocol produced higher increases in stiffness than the flexibility protocol.

This increase in stiffness can be explained by fluid loss from the IVD during testing, which can result in an increase in rigidity. For anterior-posterior and lateral shear, as well as for axial rotation, fluid loss should have a small effect on the stiffness, since the rigidity of the specimen arises from the annulus' fibres. However, during axial loading, lateral bending and flexion-extension, the nucleus provides stiffness as it is being compressed, and therefore a decrease in fluid would result in a considerable increase in stiffness. This change in stiffness occurred even though the loading applied was well below that producing any damage to the disc. Testing performed using the stiffness protocol produced a larger increase in stiffness; in this case the specimen is constrained and it is not able to move freely as it does in vivo, thus it cannot minimise the loads acting on it.

This study has shown that repeated testing over a short time period results in a change in the mechanical properties of a lumbar spinal specimen. This should be taken into account when the same specimen is tested multiple times to investigate different parameters.

#6096

Significant Demographic and Geographic Differences Exist in the Reporting of Superior Labrum From Anterior to Posterior (SLAP) Tear Literature: A Systematic Review

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Superior labrum from anterior to posterior (SLAP) pathology can result in significant pain and functional limitation for a wide variety of patients. Although many different options have been described for the diagnosis and treatment of SLAP pathology, there is little high quality evidence to support a given diagnosis/treatment method. The aim of this study was to review the global demographics and trends of SLAP literature, diagnosis, management, and consistency of reported outcomes. We identified 363 studies reporting on SLAP management over the past decade that met our inclusion and exclusion criteria. The majority of studies originated from North America (50.4%), followed by Asia (22.3%) and Europe (20.9%) with most studies describing results of operative intervention originating from the United States (58.5%). We found the majority of literature related to SLAP pathology was case series level data (44.0%) consisting of sample sizes of less than 40 patients (50.1%). The majority of studies presented clinical outcome scores with the ASES score being the most commonly reported (28.3%). The most common complications reported were pain (32.6%) and stiffness (30.4%) following surgical intervention. Current literature related to the management of SLAP pathology demonstrates a predominance of North American studies with low levels of evidence consisting of small sample sizes and variably reported clinical outcome scores. Future research should focus on multi-center, randomized studies to clarify current controversies in the surgical versus nonoperative management of SLAP pathology.

Figures

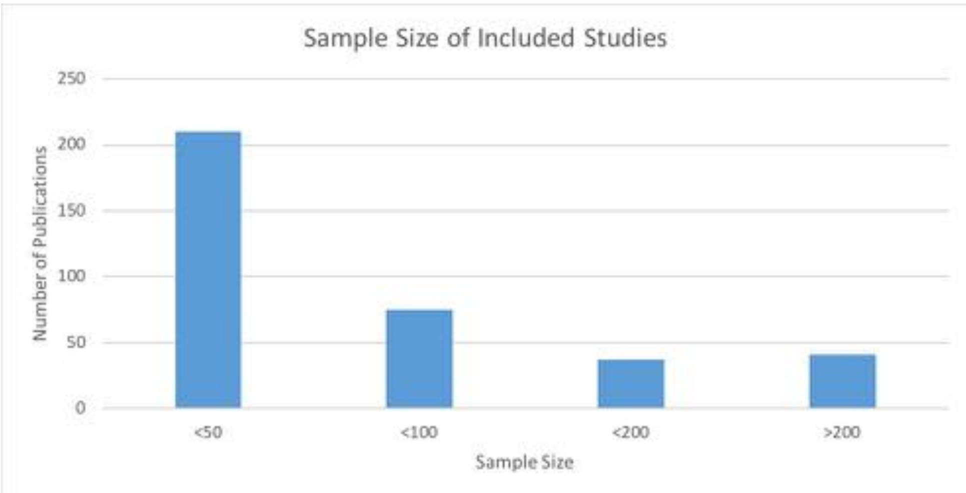

Figure 1


Level of Evidence
4%
23%
10%
48%
15%
Level 1
Level 2
Level 3
Level 4
Level 5
Figure 2

#6039

Reliability of 3D Preoperative Templating Software Systems for Humeral Head Selection in Total Shoulder Arthroplasty

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Introduction

The recreation of glenohumeral biomechanics and humeral anatomy have been shown to improve outcomes in shoulder arthroplasty, but implant positioning and restoration of optimal glenohumeral biomechanics is technically difficult. Recent research has focused on using simulation software and intraoperative instrumentation to improve implant selection and positioning mostly on the glenoid side. To date no studies have evaluated the reliability of 3D preoperative planning software for humeral side planning in total shoulder arthroplasty (TSA).

Methods

Preoperative plans were created and compared for twenty-six patients using 3 different simulation software programs: an independent preoperative planning simulation (IPPS) software (OrthoVis) and two automated manufacturer preoperative simulation (AMPS) systems: ArthrexVIP™ (AMPS I) and Tornier Blueprint™ 3D Planning (AMPS II). Variability and strength of correlations were assessed between the systems used for measurements obtained on humeral head diameter (HD) and humeral head height (HH).

Results

There were no significant differences between measured HD between the 3 systems with a mean difference of 1mm for humeral head diameter among IPPS, AMPS I and AMPS II ($p=0.964$). Humeral head height measurements recorded a mean difference of 1.7 mm between IPPS and AMPS II ($p \le 0.001$) and were not available for AMPS I. The strongest correlation when comparing humeral head measurements (diameter or depth) obtained from all systems was seen between IPPS and AMPS I for humeral head diameter ($r=0.8$; $p \le 0.001$).

Discussion

There was a high level of consistency between independent and manufacturer preoperative planning software for humeral head measurements. These preoperative planning systems can improve efficiency and workflow during surgery by guiding surgeons on implant size selection to optimally reconstruct the glenohumeral kinematics, in order to improve patient outcomes.

Figures

Figure 1. OrthoVis preoperative planning software (IPPS) and Tornier Blueprint™ 3D Planning software system (AMPS II).

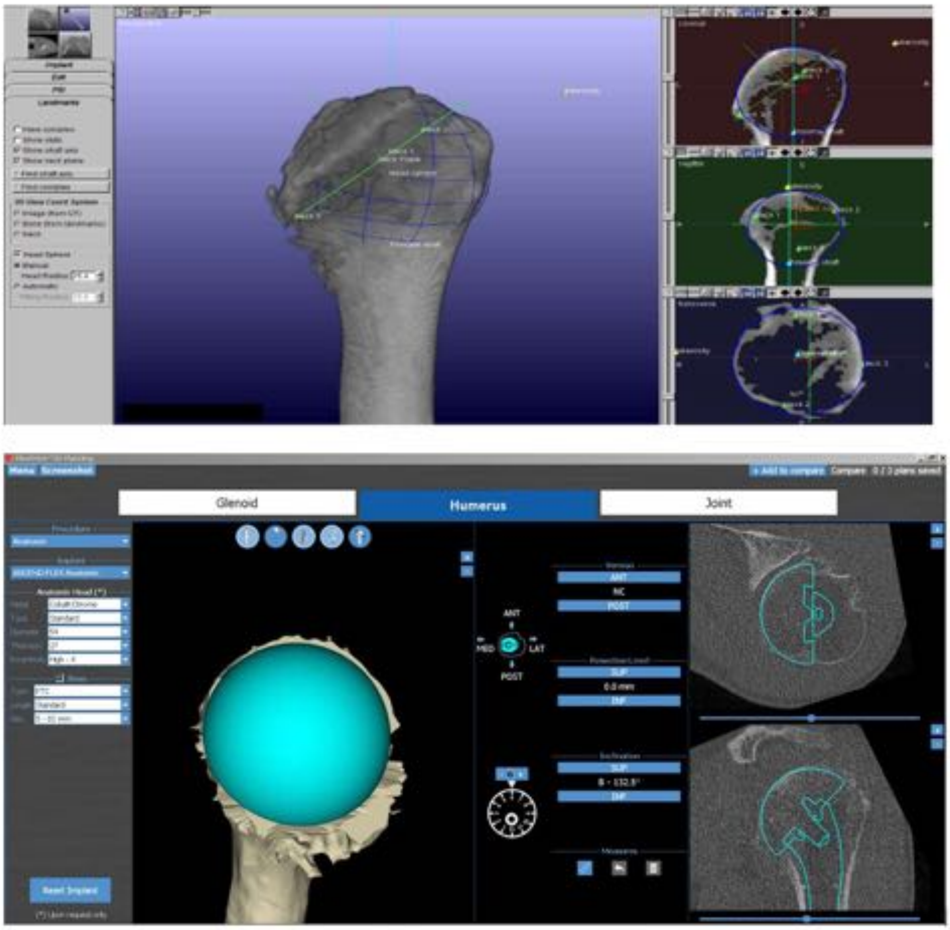

Figure 1

#6131

Evaluation of Suprainguinal Fascia Iliaca (SIFI) Block on Hip Fracture Outcomes

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Initially described in 1989, the fascia iliaca compartment block (FICB) is a unique and alternative approach to anesthetizing the femoral, LFCN, and obturator nerves for surgical procedures on the hip, thigh, and knee. This is accomplished by depositing local anesthetic into the iliac fossa where these three nerves run together. Conventionally, this block has been performed by entering the skin about 0.5 cm distal to the inguinal ligament; however, Stevens et al described a more proximal approach involving needle insertion above the level of the inguinal ligament. This study aims to ascertain any analgesic benefit conferred by the modified, or supra-inguinal, fascia iliaca (SIFI) block versus a more traditional femoral block.

IRB approval number 2017.270.C. This was a retrospective analysis of two cohorts of patients at our institution. The first cohort received a more traditional femoral peripheral nerve block, while the second cohort reviewed had been administered a SIFI peripheral nerve block. Femoral nerve blocks consisted of a single injection of equal amounts of local anesthetic, while SIFI peripheral nerve blocks consisted of an initial injection of equal amounts of local anesthetic, followed by placement of a peripheral nerve catheter that was infused with local anesthetic following completion of surgery. Post-operative opioid consumption was then evaluated at specific time intervals following admission to the post-anesthesia recovery unit.

A total of 115 patients were included in our retrospective analysis. Total post-operative opioid consumption for each patient was tabulated and then converted into standardized oral morphine equivalents. At time intervals of 8-16 hours and 24-48 hours post-operatively, there was a statistically significant decrease in the amount of opioid required for the cohort that received the SIFI peripheral nerve catheter. There was also decreased opioid usage for the SIFI cohort at the 16-24 hour interval, as well as decreased post-operative requirement for an anti-emetic that did not reach statistical significance.

With our aging population, studies estimate approximately 300,000 patients yearly have fragility-associated hip fractures and this number is increasing. This care represents a large financial and resource burden to the medical system. Fragility hip fractures typically occur in elderly patients with multiple comorbidities, putting them at risk for postoperative delirium and other postoperative complications. A recent Cochran systematic review demonstrated that preoperative peripheral nerve blocks were associated with a reduction in pain, pneumonia risk, time until mobilization, and cost. Other studies have demonstrated reduction in opioid consumption, reduced need for opioid antagonist treatment, reduction in postoperative delirium, shorter hospital stay, and improved postoperative pain score when a peripheral nerve block is used in combination with routine anesthesia care. Our study suggests that there is a potential benefit with respect to opioid consumption and, presumably, associated opioid-related side effects from performing a SIFI peripheral nerve block when compared to a more conventional femoral nerve block

#6006

A Holistic Approach to Optimize the Thromboprophylactic Strategy After Tka: A Prospective Observational Report.

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Introduction:

The on-going debate regarding the preferred thromboprophylactic strategy after TKA is governed by the balance between prevention of thromboembolic events and bleeding complications. This not only covers thromboprophylactic agent administration, but also surgical approach, anaesthesia, pain management, dressing management and swift postoperative mobilisation. We developed a holistic strategy, comprising all surgical, anaesthesiology and postoperative management considerations to minimize the risk of bleeding and thromboembolic events and quicken recovery and rehabilitation.

Materials and Methods:

For postoperative management optimisation, a new postoperative cloud-controlled Recotech® tool (moveUP, Class 1, CE-certified, medical device) was used. This tool provides interactive and remote monitoring of activity, pain scores and the rehabilitation progress, and permits therapeutic intervention or direct patient communication if required. It also provides accurate recording of the evolution of the variables of interest, and the occurrence of complications, for research purposes. The aim of this study was to investigate whether patients treated with our holistic approach would present a lower incidence of thromboembolic events and bleeding relative to the reported incidence in literature. The postoperative thromboprophylaxis protocol consists of low dose aspirin (80mg OD) started day 1 postoperatively and continued for 2 weeks after TKA.A 24/7 follow-up of the patients, combined with daily recommendation and monitoring of easy to perform mobilising exercises is believed to play a major role in the prevention of thromboembolic events.

Results:

In our cohort of 71 TKA patients, no thromboembolic events were observed (0% symptomatic deep venous thrombosis (DVT), 0% pulmonary embolism (PE)). There were no perioperative bleeding issues requiring blood transfusion nor significant bruising that has delayed the standard rehabilitation or has impacted the outcome at 3 months follow-up.

Discussion:

The very low incidence of thromboembolic events is noteworthy, compared to the general incidence of 2% reported in the literature.

Conclusion:

Optimizing the risk balance of bleeding and thromboembolic events requires a holistic approach of optimized surgical technique, anaesthesia and medication management and an individualised rehabilitation path.

#6169

A Custom-Made Cement Spacer: For a 2-Stage Revision of an Infected Megaprosthesis of the Hip

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Introduction

A 42 years old man was hospitalized for a two-stage revision of an infected megaprosthesis of the right hip. The patient was initially operated because of an osteosarcoma 20 years ago. The patient received a megaprosthesis, covering a bone defect of 16 cm (Fig. 1). A chronic low-grade infection was the reason for revision. No cement spacer was sufficiently large enough to fill the gap and to maintain soft-tissue tension. A 3D printed custom-made mold was designed, by which a custom-made cement spacer could be fabricated, intra-operatively, in order to address these problems. Postoperatively, the patiënt was not allowed to do weight bearing on the limb.

Material and methods

A 3D-model of the megaprosthesis was developed using the software Mimics and 3-Matic (Materialize NV, Leuven, Belgium). The mold was based on this 3D model, so that the stem would perfectly fit the endomedullar channel. SolidWorks (SolidWorks Incorp., Massachusettes, USA) was used to create the 3D mold (Fig. 2). Two different materials were tested on ease of extraction of the polymethylmethacrylate (PMMA) cement: polyamide (PA 12) and Acrylonitrile Butadiene Styrene (ABS). Designing and printing the mold took 3 days. The mold was lined with paraffin wax prior to insertion of the PMMA cement. During surgery, the mold was filled with 170 cm^2 PMMA cement (Palacos R+G, Heraeus, Hanau, Germany) with gentamycin, one Titanium Elastic Nail of 2mm (DePuy Synthes Companies, Warsaw, USA) and a Spacer G, short stem, size 54 (Tecres SPA, Verona, Italy). the PMMA was hand-mixed for 90 seconds and cured for 15 minutes (Fig. 3).

Results

With the use of a small chisel, the cement spacer was extracted, relative easily, out of the PA mold. The ABS mold could not be opened after the cement cured. The cement spacer fitted perfectly into the acetabulum and the endomedullar channel of the remaining distal femur. A postoperative radiography demonstrates the good position (Fig 4).

Conclusion

PA was the preferred material to build the mold, combined with the use of paraffin wax, extraction was relative easy. Custom-made cement spacers made from a 3D printed mold, is a reliable option for a 2-stage revision of a megaprosthesis, maintaining soft tissue tension, appropriately filling the cavity, eluting antibiotics and is relatively easy to fabricate in a short period of time.

Figures

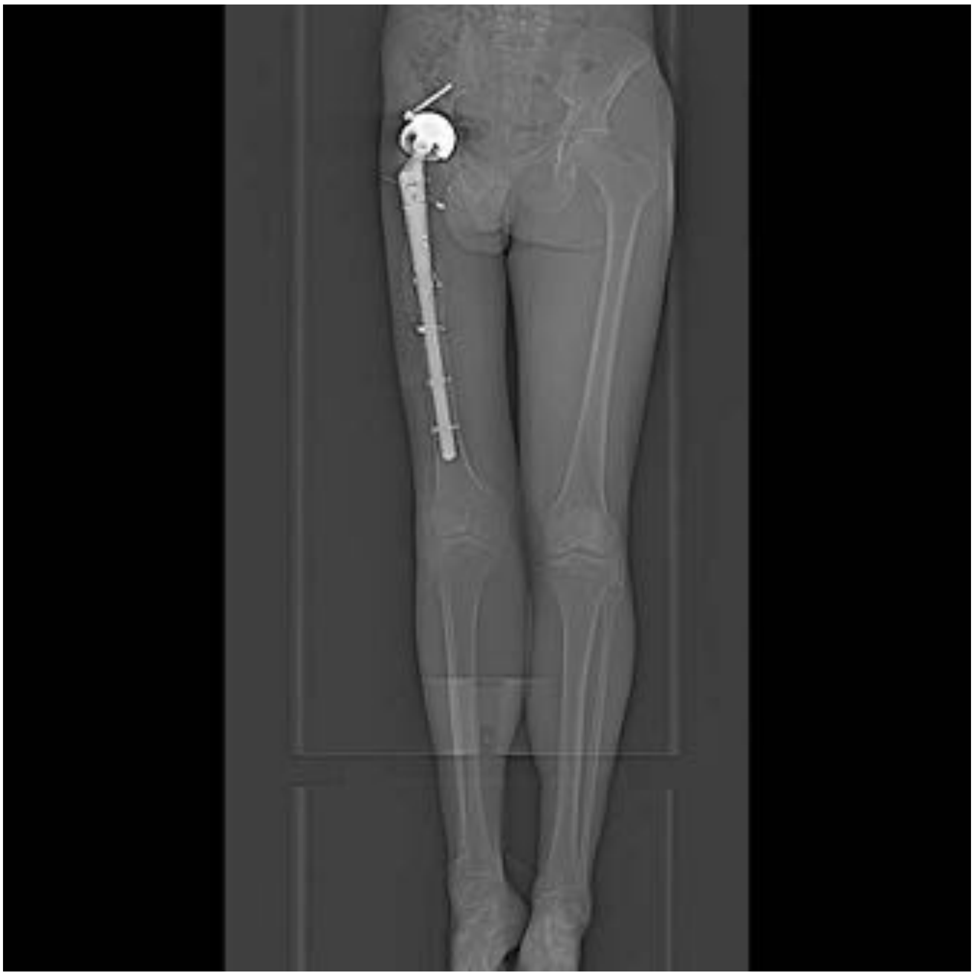

Figure 1

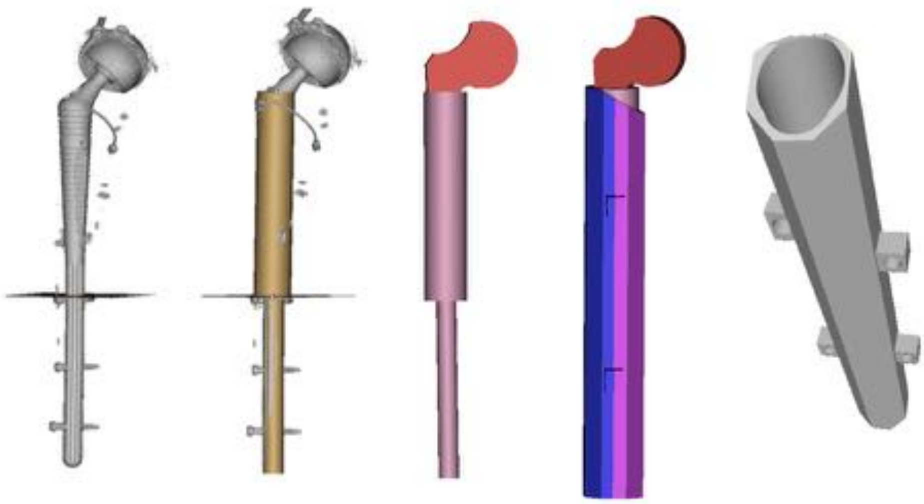

Figure 2

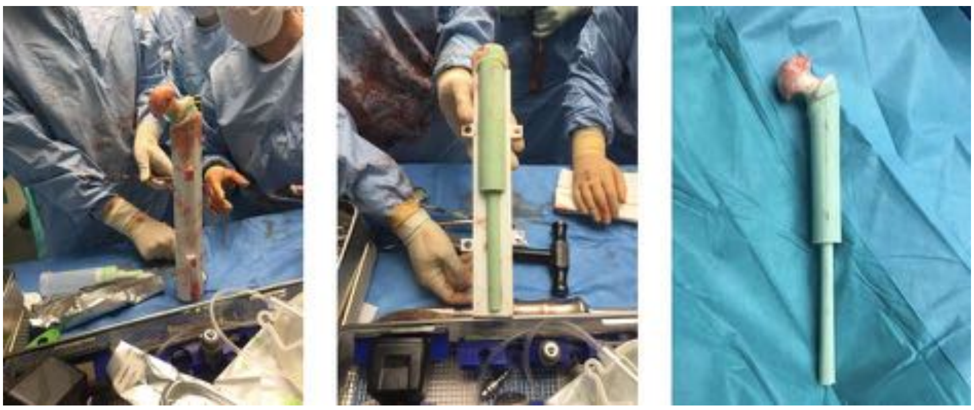

Figure 3

Figure 4

#6051

Robotic-Assisted Total Hip Arthroplasty May Reduce the Risk of Complications in Patients Younger Than 35 Years

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Introduction: As outcomes following total hip arthroplasty (THA) continue to improve, surgeons are more likely to offer this treatment to younger, more active patients. The presence of morphologic deformities and the need for a longer-lasting durable construct can pose technical challenges, making reconstruction difficult. Robotic-assisted THA platforms have been shown to improve component positioning and better restore normal kinematics when compared to conventional THA techniques. The purpose of our study is to assess the utility of the MAKO-robotic assisted THA platform in improving postoperative outcomes in patients younger than 35 years old.

Methods: A retrospective analysis of 125 consecutive patients younger than 35 years old that underwent primary unilateral THA between January 2013 and April 2018 was conducted. Patients were divided into two cohorts: (1) patients that underwent MAKO robotic-assisted THA and (2) patients that underwent conventional-THA (c-THA). All patient variables including demographics, operative details, and postoperative outcomes were carefully studied. Radiographic analysis included measurement of postoperative acetabular cup inclination and anteversion angles as well as postoperative leg length discrepancies. Chi-square and unpaired student t-tests were performed for all categorical and continuous variables, respectively.

Results: Of the total 125 patients, 29 (31 hips) patients were in the MAKO-THA cohort, and 96 (103 hips) patients were in the c-THA cohort. Patients in the MAKO-THA cohort were younger (26.6±6.2 vs. 29.0±5.3 years old; p=0.03) and had a higher mean BMI (29.8±8.2 vs. 25.7±5.9 kg/m2; p=0.03) at surgery. The most common indication for THA was DDH (45%) and osteonecrosis of the femoral head (45%) in the MAKO-THA and c-THA cohorts, respectively (Table 1). Cup inclination/anteversion angles and leg length discrepancies were similar between both cohorts. Although not statistically significant, patients in the c-THA group were more likely to experience clinically significant higher rates of dislocation (2.9% vs. 0), revision THA (6.8% vs. 0), any postoperative complication (7.8% vs. 0), and 90-day readmission (2.9 vs. 0) following primary THA (Table 2).

Conclusion: The MAKO-robotic THA platform can help improve outcomes for younger THA recipients. Future studies with larger cohorts should evaluate outcomes in this historically technically demanding patient population.

Figures

Table 1. Patient Characteristics	MAKO-THA n = 29 patients 31 hips (%)	Conventional-THA n = 96 patients 103 hips (%)	*p*-value
Age (yrs.) (mean±SD [range])	26.6±6.2 [13-35]	29.0±5.3 [15-35]	**0.03**
Gender			0.30
Male	11 (38)	38 (40)	
Female	18 (62)	58 (60)	
Race			**<0.01**
White	11 (38)	60 (63)	
African American	5 (17)	19 (20)	
Asian	1 (3)	6 (6)	
Hispanic	4 (14)	8 (8)	
Other	8 (28)	3 (3)	
Laterality			0.60
Right	14 (45)	52 (50)	
Left	17 (55)	51 (50)	
ASA (mean±SD [range])	1.9±0.6 [1-3]	1.9±0.6 [1-3]	0.86
BMI (kg/m^2) (mean±SD [range])	29.8±8.2 [15.1-54.3]	25.7±5.9 [16.6-40.4]	**0.03**
Hospital LOS (days) (mean±SD [range])	3.0±1.4 [1-6]	2.6±1.4 [0-6]	0.44
Indication for THA			0.12
Osteonecrosis	8 (26)	46 (45)	
DDH	14 (45)	26 (25)	
OA	5 (16)	10 (9)	
LCP	0	7 (7)	
RA	3 (10)	7 (7)	
Trauma	0	4 (4)	
Septic Arthritis	1 (3)	1 (1)	
JRA	0	2 (2)	
Cup Inclination Angle (°) (mean±SD [range])	41.4±4.3 [32-49]	39.8±8.5 [23-55]	0.35
Cup Anteversion Angle (°) (mean±SD [range])	17.5±5.6 [4-30]	15.8±8.7 [2-40]	0.36
LLD (mm) (mean±SD [range])	7.2±6 [0.3-20.3]	7.6±12.1 [0.8-63]	0.90

BMI = body mass index; DDH = developmental dysplasia of the hip; JRA = juvenile rheumatoid arthritis; LCP = Legg-Calvé-Perthes; LLD = leg length discrepancy; LOS = length of stay; OA = osteoarthritis; RA = rheumatoid arthritis

Figure 1

Table 2. Postoperative Outcomes	MAKO-THA n = 29 patients 31 hips (%)	Conventional-THA n = 96 patients 103 hips (%)	*p*-value
Dislocation	0	3 (2.9)	0.33
Revision THA	0	7 (6.8)	0.14
Instability	-	2	
Infection	-	2	
Aseptic Loosening	-	2	
Periprosthetic fracture		1	
Any postoperative complication	0	8 (7.8)	0.10
90-day readmission	0	3 (2.9)	0.33

THA = total hip arthroplasty

Figure 2

#5947

Dynamic Sitting to Standing Radiographs Provide More Accurate Evaluation of Functional Mechanics in Total Hip Arthroplasty

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Introduction: Patients with coexisting spinal disease and hip osteoarthritis (OA) are limited in their ability to change pelvic tilt from standing to sitting secondary to limited hip range of motion. As OA severity worsens so does global sagittal alignment. There is a particularly high rate of instability and dislocation after total hip arthroplasty (THA) in these patients despite having acetabular cup positioning traditionally thought of as within acceptable alignment. The purpose of our study was to determine which radiographic images are required to determine sitting to standing mechanics in THA.

Methods: Patients with full body sitting-standing stereoradiographs at a single institution were included. Hip OA severity was graded by the Kellgren-Lawrence grades. Spinopelvic parameters (Pelvic Incidence (PI), Pelvic Tilt (PT), Lumbar Lordosis (LL), and PI-LL), Thoracic Kyphosis (TK; T4-T12), global spinal alignment (SVA and T1-Pelvic Angle; TPA; T10-L2), and hip flexion (difference between change in PT and change in proximal femoral shaft angle) were also measured. Patients were divided into two groups based on imaging position: Relaxed (normal standing and relaxed sitting) and Dynamic (single leg extension and flexed seated). Propensity score matching was used to control for gender, BMI, and hip OA grade. Independent samples t-tests and ANOVA were used analyze segmental alignment between sitting and standing, and between pathology groups.

Results: In total, stereoradiographs of 100 relaxed patients were compared to 100 dynamic patients. Dynamic imaging in the flexed seated position showed greater effects of lumbar lordosis and pelvic tilt in functional positions.

Discussion: Dynamic imaging displays the compensatory mechanisms of patients with concomitant hip and spine pathology more effectively, and reproducibly mimics high-risk dislocation positions in THA. We recommend the inclusion of more dynamic images for proper hip-spine THA functional planning.

#5712

Surgeon Volume Does Not Influence Short-Term Outcomes Following Robotic-Assisted Medial Unicompartmental Knee Arthroplasty

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Background: Increased complication rates have been described in low volume unicompartmental knee arthroplasty (UKA) surgeons compared to high volume surgeons. However, studies assessing outcomes in robotic-assisted UKA based on surgeon experience by yearly case volume are lacking. The purpose of this study is to compare short-term outcomes between surgeons performing an annual 15 or fewer robotic-assisted UKAs, and those performing more than 15 annually.

Methods: We retrospectively reviewed 136 consecutive robotic-assisted medial UKA cases from 2011 to 2014 at a tertiary care center. Minimum follow-up was 24 months for all patients. Intra-operative details and post-operative outcomes were recorded. Annual revision rate (ARR) was calculated for both cohorts.

Results: There were no differences between the cohorts for discharge disposition (p=0.530), LOS (p=0.493), and rates of returns to OR (p=0.579), revisions (p=0.231), or complications (p=0.054) [Fig. 1]. The overall ARR was 0.72 and was higher in the ≤15 group (2.44) than the >15 cohort (0.30) [Fig. 2].

Estimated blood loss (EBL) was significantly higher in the≤15 cohort (98.1 mL vs 67.8 mL; p=0.019), however, this 30 mL difference was not clinically significant. There were no differences in tourniquet time (p=0.526) and length of surgery (p=0.876). No intra-operative complications were observed in either cohort [Fig. 3].

Conclusion: There are no differences in short-term robotic-assisted UKA outcomes between surgeons who perform ≤15 annual cases and those who perform >15 annual cases. Robotic-assisted UKA is a successful procedure in the hands of both high- and low-volume surgeons.

Figures

Figure 1. Short-term postoperative outcomes

Postoperative Outcomes	≤15 (n=29)	>15 (n=107)	p-value
Discharge disposition, (%) *- Home* *- Rehabilitation facility*	28 (96.6) 1 (3.4)	100 (93.5) 7 (6.5)	0.53
Length of stay, days (SD)	2.4 (±1.3)	2.2 (±0.9)	0.493
Returns to operating room (%)	3 (10.3)	11 (10.3)	0.579
Revisions (%)	2 (6.9)	1 (0.9)	0.231
Complication, (%)	1 (3.4)	0	0.054

Abbreviations: SD: standard deviation

Figure 1

Figure 2. Annual revision rates between cohorts

Cohort	Number of UKA	Mean follow-up (months)	Number of revisions	Total observed years	Annual revision rate
≤15 annual robotic UKAs	29	40.4	2	82.0	2.44
>15 annual robotic UKAs	107	43.0	1	332.0	0.30
Total	136	42.4	3	414	0.72

Abbreviations: UKA: unicompartmental knee arthroplasty

Figure 2

Figure 3. A comparison of intraoperative details between surgeons performing 15 or fewer annual robotic-assisted UKAs and those performing greater than 15 robotic-assisted UKAs

Intraoperative Details	≤15 (n=29)	>15 (n=107)	p-value
Estimated blood loss, ml (SD)	98.1 (±84.1)	67.8 (±37.0)	0.019
Tourniquet time, minutes (SD)	115.8 (±39.9)	120.2 (±30.2)	0.526
Length of surgery, minutes (SD)	149.9 (±47.4)	148.3 (±49.1)	0.876
Intraoperative complications	0	0	N/A

Abbreviations: SD: standard deviation; UKA: unicompartmental knee arthroplasty

Figure 3

#5832

A Large Proportion of Revision Total Hip Arthroplasty Is Potentially Preventable

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Introduction: As surgeons, we have a moral obligation to address potentially preventable complications in an effort to improve total hip arthroplasty (THA) outcomes. The goal of this study is to identify and report potentially preventable causes for revision THA (rTHA).

Methods: A retrospective review of 352 consecutive patients that underwent rTHA or re-revision THA from August 2015 to August 2017 was conducted. 138 of these were identified as primary to rTHA within a 5 year interval. Three adult reconstruction fellowship trained surgeons reviewed perioperative parameters and classified rTHA recipients into two categories: preventable rTHA and non-preventable rTHA. Agreement amongst the reviewing surgeons was 98%. Basic demographics, surgical characteristics for the primary THA (pTHA), and pre- and post-rTHA variables were analyzed.

Results: Sixty (43.5%) rTHAs were deemed preventable. Of these rTHA recipients, 20 were male and 40 were female. Mean age at time of rTHA was 61.5 years and mean body mass index was 27.8 kg/m^2. The following were identified as preventable reasons for rTHA: component malpositioning (47%), intra-operative fracture (28%), aseptic loosening (10%), femoral component subsidence (10%), and leg length discrepancy (5%). Eighteen (30%) patients were revised for instability. Of these, 10 (56%) were placed within Lewinnek's “Safe Zone” of which 9 (90%) had prior spino-pelvic pathology that was not properly addressed during pTHA. The most common bearing surface during pTHA was cobalt chrome on highly cross-linked polyethylene (40%). The most common femoral head size was 36mm (38%). Technology was used for assistance in 8.3% of pTHAs. Four patients (6.7%) underwent re-revision THA, three for instability and one for aseptic loosening.

Conclusion: A high proportion (43.4%) of rTHA is potentially preventable. Furthermore, surgeons are responsible for carefully evaluating causes for rTHA and identifying new methods to address these issues. Only 8.3% of these preventable complications utilized technological assistance during pTHA. It is not acceptable to cause preventable harm to patients when technologies are available that may prevent this. Surgeons are morally obligated to use these technologies if they eliminate preventable harm from a patient. A step-by-step algorithm was developed for more sophisticated preoperative planning. Robotics and computer navigation technologies have been implemented to see if revision rates decrease.

Figures

Table 1. Patient Demographics at Index THA	
	n = 60 patients (%)
Age at surgery (yrs.) (mean ± SD [range])	61.5±15.5 [27-88]
Gender	
Male	20 (33)
Female	40 (67)
Laterality	
Right	31 (52)
Left	29 (48)
BMI (kg/m^2) (mean ± SD [range])	27.8±6.3 [17-49]
ASA Score (mean ± SD [range])	2.4±0.7 [1-4]
I	3 (5)
II	29 (48)
III	20 (33)
IV	2 (3)
Unknown	6 (11)
Revision THA Follow-Up (months) (mean ± [range])	12.3±8.0 [3-30]
Indication for THA	
AVN	47 (78)
OA	4 (7)
IA	3 (5)
Trauma	2 (3)
Unknown	4 (7)
CCI (mean ± [range])	2.55±1.9 [0-7]
Surgical Approach	
Posterior	29 (48)
Direct anterior	15 (25)
Other (anterior/rottinger & direct lateral)	6 (10)
Unknown	10 (17)
Discharge Disposition	
Home	31 (52)
SNF	6 (10)
Rehab Facility	3 (5)
Revision occurred during index admission	7 (12)
Unknown	13 (21)
Technology assistance	
Computer navigation	1 (2)
Robotics	4 (7)
Femoral Head Size (mm)	
<32	23 (38)
>32	24 (40)
Unknown	13 (22)
Surgical Case Time (minutes) (mean±[range])	137.1±54.0 [49-367]

American Society of Anesthesiologists = ASA; AVN = avascular necrosis; BMI = body mass index; CCI = Charlson comorbidity index; IA = inflammatory arthritis; OA = osteoarthritis; THA = total hip arthroplasty

Figure 1

Table 2. Reasons for Preventable Revision THA	Value (%)
	n = 60 patients (%)
Cup Malpositioning	42 (47)
Spino-Pelvic Alignment Not Addressed	9 (29)
Intraoperative Fracture	17 (28)
Aseptic Loosening	6 (20)
Femoral Component Subsidence	6 (10)
Leg Length Discrepancy	3 (5)

THA = total hip arthroplasty

Figure 2

Figure 1. Revision THA for Instability

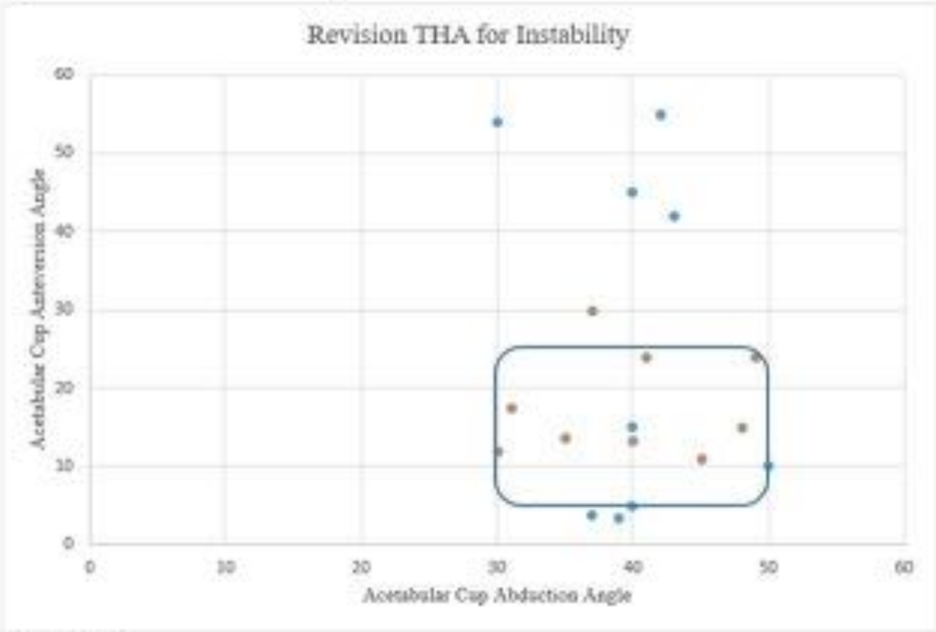

Figure Legend

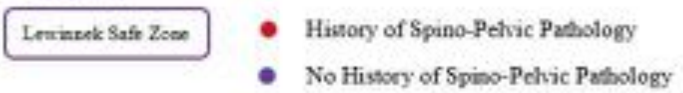

Figure 3

#5957

Robotic-Assisted Total Hip Arthroplasty Improves Patient Reported Outcomes

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Introduction: Total joint arthroplasty is regarded as a highly successful procedure. However, patient outcomes and implant longevity require proper alignment and prosthesis position. Robotic-assisted total hip arthroplasty (THA) has been found to improve the accuracy of component positioning and reduce rates of revision, however there remains debate whether it provides improvements in patient reported outcomes (PROs). The purpose of our study was to compare PROs between robotic-assisted and conventional THA.

Methods: A retrospective review of all total hip arthroplasty patients was conducted using a single institution's FORCE database for reporting PROs. Hip disability and Osteoarthritis Outcome Score for Joint Replacement (HOOS JR), procedure satisfaction, physical component summary (PCS), and mental component summary (MCS) were compared between Mako robotic-assisted THA and conventional THA.

Results: Robotic-assisted THA had a higher average HOOS JR (84.5 vs 66.0) compared to conventional THA. The average procedural satisfaction (4.4 vs 4.3), PCS (37.7 vs 37.8) and MCS (53.1 vs 51.5) were equivalent between computer-assisted and conventional THA, respectively.

Discussion: Robotic-assisted THA improves patient reported outcomes while providing equal satisfaction compared to conventional THA.

#5711

Open Labral Reconstruction Improves Outcomes in Femoroacetabular Impingement After Failed Hip Preserving Surgery

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Objectives: Although hip arthroscopy (HA), has gained popularity in the treatment of femoroacetabular impingement (FAI), clinical failures requiring reoperation still occur. The purpose of this study is to report clinical and radiographic outcomes in patients undergoing open labral reconstruction via Surgical Hip Dislocation (OLR-SHD) after failed HA.

Methods: In a retrospective review of all hip surgeries in single center from January 1st, 2013 to September 30th, 2017 we identified 18 OLR-SHD procedures. History of HA and demographic data including age, gender, race, body mass index (BMI), American Anesthesiology Society (ASA) score, and side of procedure were collected. Pre- and post-operative Harris Hip Scores (HHS), modified Merle d'Aubigne (MMD) scores, and Tönnis osteoarthritis grade were collected. Simple linear regression analysis was performed for all individual demographics and history of HA for pre- and post-operative HHS, and MMD scores. Sub-analysis was performed using a multivariable logistic regression while controlling for individual variables.

Results: Patients with a history of HA had significantly lower pre-operative HHS (p=0.044), and significantly greater overall improvement of HHS (p=0.026) and MMD (p=0.017) scores, from baseline, after undergoing OLR-SHD. There was no difference in pre-operative MMD, nor post-operative HHS and MMD scores.

Conclusions: Failure of HA leads to significantly lower clinical outcomes. OLR-SHD after failed HA allows greater surgical exposure to resolve underlying bone deformities and provide equivalent post-operative clinical outcomes compared to those without failed prior HA.

#5713

Sagittal Spine Disease Alters Sitting-Standing Lumbopelvic Mechanics: Implications for Total Hip Arthroplasty

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Introduction: Postural changes between sitting and standing affect lumbopelvic alignment and pelvic tilt (PT). This is particularly important for patients with coexisting hip and spine disease, as a patient's lumbopelvic mechanics have direct implications on the functional positioning and stability of the acetabular component of a THA. The purpose of this study was to evaluate the differences in lumbopelvic parameters in two prominent weight-bearing positions among patients with varying severities of sagittal spine disease (SSD).

Methods: This study was a retrospective radiographic review of patients with full-body sitting and standing radiographs. Imaging was performed using the EOS modality, which allows for simultaneous orthogonal radiographic image acquisition with the patient in physiologic weight-bearing positions. Sagittal spinopelvic parameters were measured, including pelvic incidence (PI), PT, lumbar lordosis (LL), femoral shaft angle (FSA), and PI-LL mismatch. Patients were categorized into three groups based on spinal pathology: normal, degenerative (loss of disc height greater than 50%, facet arthrosis, or any spondylolisthesis), and lumbar flatback deformity (PI-LL greater than 10 degrees). Global and regional spinopelvic parameters in both the standing and sitting positions were compared using ANOVA.

Results: 580 patients met the inclusion criteria. 203 patients (35.0%) were placed in the normal group, 264 (45.5%) in the degenerative group, and 113 (19.5%) in the flatback group. After propensity score matching for OA grade and PI, 264 patients (88 in each group) were included in the analysis.

When standing, the flatback group demonstrated increased decreased LL (41.65 ± 16.04 vs 61.93 ± 8.83 and 58.85 ± 10.83, p<0.001), increased PT (23.96 ± 7.64 vs 13.64 ± 6.47 and 15.95 ± 6.34, p<0.001), increased FSA (10.16 ± 4.81 vs 6.79 ± 3.92 and 8.01 ± 4.81, p<0.001), and greater sagittal imbalance compared to the normal and degenerative groups, respectively.

In the sitting position the flatback group demonstrated increased PI-LL mismatch (27.51 ± 13.97 vs 17.39 ± 20.32 and 15.61 ± 16.03, p<0.001) and decreased LL (30.77 ± 16.83 vs 36.93 ± 15.12 and 41.20 ± 16.72, p<0.001). Difference in sitting PT did not reach statistical significance (26.05 ± 17.79 for normal, 28.20 ± 14.30 for degenerative, 31.36 ± 13.89 for flatback, p=0.073).

The flatback group underwent less change in PT with the positional change from standing to sitting compared to the degenerative group (7.40 ± 13.24 vs 12.24 ± 15.08, p=0.025) and the normal group (7.40 ± 13.24 vs 12.41 ± 17.18, p=0.032). Likewise, the flatback group showed less change in LL from standing to sitting (-10.88 ± 11.03 vs -25.00 ± 14.35 vs -17.65 ± 14.27, p<0.001).

Conclusion: The severity of spinal pathology has a significant impact on lumbopelvic mechanics during postural changes. Because compensation for severe sagittal misalignment requires near maximal standing hip extension, the pelvis experiences significantly less change in spinopelvic tilt when transitioning to the seated position. This may limit the safe zone for acetabular component placement for SSD patients undergoing THA. Surgeons performing THA should consider the implications of concomitant spinal pathology and the potential impact on functional positioning of the components.

#6047

Improved Component Positioning in Computer-Assisted Birmingham Hip Resurfacing

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Introduction: Hip resurfacing is a surgical option for young and active patients with osteoarthritis. Early failures of this complex procedure are often due to improper implant placement. However, excellent midterm outcomes have been reported with computer-assisted Birmingham hip resurfacing (BHR). The purpose of our study was to assess the utility of computer-assistance technology in the effort to improve implant positioning and post-operative outcomes following BHR.

Methods: A retrospective analysis of 222 consecutive patients at a single institution was performed comparing computer-assisted BHR and conventional BHR. Patient demographics included age, gender, BMI, history of prior hip surgery, and operative laterality were recorded. Perioperative details including length of stay (LOS), discharge disposition, surgical time, estimated blood loss (EBL), and intraoperative complications were noted. Radiographic analysis of implanted femoral head size, cup inclination, cup anteversion, leg length (LL), offset, and hip center of rotation was performed. Postoperative complications, revisions, and re-operations were also recorded. Chi-square and unpaired student t-test were performed for all categorical and continuous variables, respectively.

Results: Of the total 222 consecutive BHRs, 218 were male while only 4 were female. Computer-assisted navigation was performed in 59 BHR cases and conventional BHR was performed in 163 cases. On average, the LOS in the computer-assisted cohort was 0.85 days and 100% of patients were discharged home. The average surgical time of computer-assisted BHR was 126 minutes with an average EBL of 307.9 mL. No intraoperative complications or revisions were noted in either cohort. 3/163 conventional and 2/59 computer-assisted BHRs experienced infection and required irrigation and debridement.

A size 47 femoral head was implanted in 49%, size 50 in 31%, size 52 in 12%, and size 54 in 8% of computer-assisted BHRs. Computer-assisted navigation during BHR positioned the cup in an average of 40.2^{o} of inclination and 12.1^{o} of anteversion. The average LL using computer-assistance was 6.9 mm with an average offset of -3.1 mm. The hip center of rotation was changed 2.2 mm superiorly, 3.8 mm medially, and 0.4 mm posteriorly on average.

Conclusion: Computer-assisted technology allows surgeons to achieve improved component positioning and reduce the risk of early failures.

#5878

The Effect of Combined Application of Calcium Polyphosphate Granules and bFGF Fibrin Glue for Tendon-Bone Healing in the Tibial Tunnel in a Rabbit ACL Reconstruction Model

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ObjectiveThis study was designed to investigate the effect of combined application of calcium polyphosphate granules and bFGF fibrin glue for tendon-bone healing in a rabbit ACL reconstruction mode.

Methods Seventy-two male New Zealand white rabbit were divided into 4 groups (n=18 for each group) to receive bilateral ACL reconstruction using the long digital extensor tendon autograft: Group A (Nothing added into the tendon-bone interface), group B (CPP granules and fibrin glue without bFGF), group C (bFGF 600 mg/ml in fibrin glue), and group D (CPP granules and bFGF 600 mg/ml in fibrin glue). The decalcified histological sections were stained with Hematoxylin-Eosin, Masson and safranin O for histological scoring. Immunohistochemical stain of Col-I, Col-II, VEGF and OCN were done.

Results

Histological results indicated that the quality of tendon-bone healing in group B and D were better among groups. Immunohistochemical analysis showed high express of VEGF in group C and D, and high express of OCN and Col-I in group B and D. The BMD values were higher in group B and D. Micro-CT showed peri-graft bone mass and microarchitecture in group D were higher than the other groups. The ultimate failure load and stiffness of group D were the highest among the four groups at week 6 after surgery.

Conclusion

The bFGF, CPP and combined use of them could significantly improve tendon-bone healing in the tibial tunnel and promoted osteogenesis and fiber connection at the tendon-bone interface after ACL reconstruction in the rabbit model.

#5529

Clinical Diagnosis of Instability in TKA:

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Design and evaluation of a new diagnostic Algorithm for the diagnosis of the unstable total knee Arthroplasty

Introduction

When considering Revision knee Arthroplasty, the key factory in achieving a satisfactory outcome is an accurate pre-op diagnosis. Prior to this study our registry data showed a high incidence of revision surgery for Pain and Patello-femoral pain. This paper describes and evaluates a new algorithm to improve diagnostic accuracy in the failing knee and reduce the risks of unnecessary surgery to the patient.

Method

In this study, we retrospectively examined the records of 45 patients who had undergone our diagnostic EUA at a single hospital centre for post-operative complications following a primary TKA. All procedures were performed by the senior author. Results were analysed to investigate any associations between EUA findings and the clinical need for revision surgery.

Results

There is no difference in the rate of revision between males or females. Knee joint aspirates and inflammatory markers as unpredictable tests for predicting whether revision surgery is required. Varus Instability on Fluoroscopic examination was the most reliable predictor ($p>0.001$). Intrinsic injection testing excluded 33% of patients who did not require revision surgery.

Conclusions

Our results confirm it is possible to set up a standardised diagnostic and management pathway for Revision TKA surgery. This has reduced the number of patients having revision surgery performed for ‘pain’ and has hopefully reduced unnecessary procedures. Higher rates of ‘minor revisions’ are performed with a lower rate of complications, lower costs and potentially reduced rates of re-revision for our patients.

#5527

Results of Revision Total Knee Arthroplasty Due to Instability

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Abstract

Introduction

Revision TKA for instability is a significant problem and is one of the most common causes of early failure in TKA surgery. Patients not only undergo revision surgery early, but they have a high rate of re-revision surgery in the first 5 years. In Australia revision TKA procedures cost approximately $63,000 AUD. The aim of this study is to evaluate the results of revision TKA surgery for patients diagnosed and managed using our treatment algorithm.

Methods

All revision cases diagnosed using our new algorithm and performed for instability at the Repatriation General Hospital between January 2012 and December 2016 were reviewed.

Patient's records were reviewed for complications and re-revision rates identified using an AdHoc AOANJJR report. Post op clinical outcomes were evaluated using the oxford knee score.

Results

26 patients were identified between January 2012 and December 2016 inclusive. A total of 9 males and 17 females with average ages of 70.00 ± 11.56 and 67.12 ± 9.50 years respectively were included. 25 patients were found to have had revision knee procedures, with one found to have only had a primary TKA procedure. Two patients had further revision procedures on the same knee confirmed via the AOANJRR, whilst 7 patients did not respond to follow-up.

Conclusions

Our results show that using our diagnostic treatment algorithm TKA patients can be revised for instability with acceptable clinical outcomes and a low risk of re-revision TKA surgery. Our registry data confirms a reduction from 14.6 to 8.3% leading to less invasive repeat surgery for our patients and a significant cost saving for our department.

#5580

Prospective Evaluation of the MAKO Robotic System in Total Knee Arthroplasty

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Introduction & aims

The MAKO Robotic system has been in use in Australia for TKR surgery since 2017. It is combined with the Triathlon TKR implant which has good mid-term results. Since then a MAKO registry has been set up to assess the results of TKR patients in Australia and New Zealand.

The aim of this study was to monitor patient outcomes and compare local results with the MAKO registry to ensure patient safety is maintained.

Method

A prospective cohort of 100 patients undergoing MAKO TKR surgery was enrolled. Data was collected on pre-op planning, intra op measurements and post op alignment measurements.

Secondary objectives recorded were length of stay, surgical time, surgeon satisfaction. And patient’s outcomes recorded with PROMs.

Results

Data collection is ongoing at the time of submission and will be available for presentation.

Conclusions

We hope to confirm the safe introduction of this technology with accurate execution of pre op planning and good clinical outcomes for our patients.

ACL Reconstruction Without the Use of a Tourniquet

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Background:

Sport injuries are common in athletes, with an estimated 200,000 anterior cruciate ligament (ACL) tears in the United States alone[1]. Most ACL tears are currently managed by arthroscopic reconstruction surgery, with an increase rate of 37% [2]. A tourniquet is routinely applied to achieve a bloodless field, and improve vision intra-operatively[3]. However, its use can be associated with adverse effects including muscle atrophy, metabolic changes, numbness, and increased post-op pain[4-7]. We describe a technique whereby ACL reconstruction is performed without employing a tourniquet.

Technique:

The technique involves an intra-articular injection of 10-15mg/kg tranexamic acid into the knee prior to drilling the femoral and tibial tunnels, whilst the ligaments are harvested. This technique was performed on 15 consecutive ACL reconstructions at our institution. We noted considerable reduction of 50% in knee swelling (Fig 1), 50% improvement in the range of motion (Fig 2), as well as 30% reduction in overall opioid consumption.

Discussion:

We postulate that performing ACL reconstruction without a tourniquet will eliminate ischemia, thereby avoiding re-perfusion injury and an exaggerated inflammatory response.

Figures


Figure 1


Figure 2

#5919

Sleep Apnea Is a Risk Factor for Postoperative Complications Following Primary Total Joint Arthroplasty

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BACKGROUND: Sleep apnea (SA) negatively affects bone mineralization, cognition, and immunity. There is paucity in the literature regarding the impact of SA on total joint arthroplasty (TJA). The purpose of this study was to compare complications in patients with and without SA undergoing TJA.

METHODS: A retrospective review from 2005 – 2014 was conducted using the Medicare Standard Analytical Files of the PearlDiver supercomputer (PearlDiver Technologies, Fort Wayne, IN). Patients with and without SA on the day of the primary TJA were queried using the International Classification of Disease, ninth revision (ICD-9) codes. Patients were matched by age, gender, Charlson-Comorbidity Index (CCI), and body mass index (BMI). Patients were followed for 2 years after their surgery. 90-day medical complications, complications related to implant, and 1-year mortality were quantified and compared. Logistic-regression was used to calculate odds-ratios (OR) with their respective 95% confidence interval (95%CI) and *p*-values.

RESULTS: After the random matching process there were 529,240 (female = 271,656, male = 252,106, unknown = 5,478) patients with (TKA = 189,968; THA = 74,652) and without (TKA = 189,968; THA = 74,652) SA who underwent primary TJA between 2005 – 2014. Patients with SA undergoing primary TKA had greater odds of needing transfusions (OR: 5.86, 95%CI: 3.39 – 10.14, p<0.001), developing respiratory complications (OR: 4.81, 95%CI: 4.12 – 5.63, p<0.001), and developing digestive system complications (OR: 3.69, 95%CI: 2.00 – 6.81, p<0.001) compared to patients without SA. Similarly, patients who underwent primary THA with SA had greater odds of developing SOB (OR: 4.12, 95%CI: 3.25 – 5.22, p<0.001), cardiac complications (OR: 3.36, 95%CI: 1.71 – 6.59, p<0.001), and thrombocytopenia (OR: 3.20, 95%CI: 1.93 – 5.29, p<0.001) compared to patients without SA undergoing THA. SA increased the odds of patients needing TKA revisions (OR: 1.43, 95%CI: 1.24 – 1.65, p<0.001), developing peri-prosthetic infections (OR: 1.27, 95%CI: 1.09 – 1.47, p <0.001), and dislocation of prosthetic joint (OR: 1.28, 95%CI: 1.17 – 1.40, p<0.001) compared to patients without SA undergoing primary TKA. Similar results were seen in patients with SA undergoing THA having greater odds of developing periprosthetic osteolysis (OR: 2.50, 95%CI: 1.55 – 4.01, p = 0.001), articular bearing surface wear (OR: 1.91, 95%CI: 1.26 – 2.89, p<0.001) and broken periprosthetic joint implant (OR: 1.77, 95%CI: 1.39 – 2.27, p<0.001). Patients with SA undergoing primary TKA had greater odds (OR: 2.50, 95%CI: 1.40 – 4.46, p < 0.001) of 1-year mortality compared to patients without SA. Similarly, SA patients with THA also had greater odds (OR: 1.06, 95%CI: 0.53 – 2.10, p = 0.86), but no statistical significance was found with patients undergoing primary THA with SA.

CONCLUSION: The study illustrates an increased risk of developing postoperative complications in patients with SA following primary TJA. Surgeons should educate patients on these adverse effects and encourage the use of continuous positive airway pressure (CPAP) which has shown to mitigate many of these postoperative complications.

#5941

Hypothyroidism Increases 90-Day Complications in Patients Following Primary Total Hip Arthroplasty: A Retrospective Analysis

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Background: Hypothyroidism is common, and the incidence has been increasing annually in the United States. Abnormalities in thyroid hormone can have several effects on the endocrine, immune and musculoskeletal systems of the body. The influence of hypothyroidism on outcomes following primary total hip arthroplasty (THA) is not well reported. We hypothesized that hypothyroidism was associated with a higher risk of postoperative complications and 90-day costs following primary THA.

Methods: A thorough evaluation of the Medicare Standard Analytical Files was performed for patients undergoing primary THAs from 2005-2014. Utilizing International Classification of Disease 9th revision (ICD-9) codes we identified patients who underwent THA. Patients with a concurrent diagnosis of hypothyroidism were matched by age, gender, and Charlson-Comorbidity Index (CCI), to a control group. Ninety-day postoperative complications, readmission rates, complications related to implants, and cost of care were compared and assessed following primary THA between matched cohorts.

Results: A total of 383,898 patients underwent primary THA. 191,949 with a diagnosis of hypothyroidism and 191,949 matched patients without hypothyroidism. Hypothyroidism was associated with greater odds of postoperative complications ($p<0.001$), 90-day readmission rates ($p<0.001$), and complications related to implant failure, such as: mechanical complications (OR: 3.94, $p<0.001$), articular bearing surface wear (OR: 2.00, $p<0.001$), and broken implants (OR: 1.97, $p<0.001$).

Conclusion: This study demonstrated an increased risk of postoperative complications (medical or implant related), increased readmission rates and higher costs among patients with hypothyroidism following primary THA. Surgeons should counsel patients and determine strategies to medically optimize patients to mitigate risk and decrease cost.