Oral Presentations

A1-1

11 YEARS CLINICAL EXPERINCE OF LATERALFLARE™ CEMENTLESS STEMS FOR JAPANESE PATIENTS AIDED BY 3D COMPUTER PREOPERATIVE PLANNING SYSTEM – CAD-CAM CUSTOM STEM AND OFF-THE-SHELF REVELATION® STEM

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An arthritic hip should have its biomechanically stable order even it is not physiological. In total hip arthroplasty (THA), we should destroy it more or less. Then we reconstruct new order again. To obtain biological load transfer after THA, we have been developing Lateralflare™ stem with high fit-&-fill since 1989. It was implemented on custom stem hen on off-the-shelf (OTS) stem.

Custom stem was started using since 1995 and OTS was since 2001 in Japan. Japanese femur is said that it has quite characteristic geometry and would have difficulty in using high fit-&-fill stem designed by international standard. For its solution we have developed a 3D preoperative planning system. All cases of the total hip arthroplasty and some cases of femoral neck fracture cases were examined preoperatively.

320 hip surgeries done with Lateralflare™ stems including 38 custom and 282 OTS stems were reviewed. 61 males 22-101 years old 259 females 30-102 years old, in average 68.4 were operated. UntilOTS stem became in service, only patients with severe deformity or young active patients were treated with custom stems and the others were treated with cemented stems. After OTS stem became in service, all cases were treated with Lateralflare stems. Almost for all cases, OTS stems could be used even for DDH cases except for 10 custom cases. First, 3D preoperative planning was done. Custom stems were used only when some problems were found with OTS stems. The main reason for choosing custom stem was ante version adjustment. OTS stems reproduce preoperative center of the femoral head, but we have found that some patients automatically reduced the excessive ante version making osteophytes. For those cases, custom stems were designed to keep reduced ante version. The second reason was prior subtrochanteric osteotomy. The third was severe deformity. Almost in all cases spot welds were observed around lesser trochanteric level within 3 months. Only three among all were revised because of non stem originated problems. One case was revised because of MRSA infection expanded from the sacral pressure sore. The second case had tumbled down 2 weeks after the surgery and the cementless cup shell was moved. The stem was intact at the surgery but it happened before bone ingrowth, the stem was revised too. The third case also tumbled 3 weeks after the surgery then proximal femoral fracture had happened. Multi-fiber wires were used to fix the fragments. Two month later MRSA infection became remarkable in the hip then the stem was removed. In 3 cases 2~8mm distal migration was observed. Two cases were only 2mm migration in primary case and the other was 8mm migration in revision case with custom stem. In this case if bigger Lateralflare had been designed it would not happen. Good proximal load transfer and clinical results were obtained by Lateralflare custom and OTS stems for Japanese.

A1-2

METAL-ON-METAL CEMENTLESS TOTAL HIP ARTHROPLASTY WITH CONICAL STEM FOR ARTHRITIS FOLLOWING CONGENITAL HIP DISEASE

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In recent years cementless cone tapered stems reached a large success in Hip revision surgery, literally revolutioning the prognosis of many cases of dramatical bone stock loss.

Nevertheless, little experience exists in the Literature about their use in primary arthroplasties. The Cone Stem was designed in the 80's by Prof. Wagner. The stem is made of a rough blasted Titanium Alloy with a cone angle of 5° and 8 sharp longitudinal "ribs" that cut into the inner cortex, providing excellent rotational stability: The ribs depth of penetration ranges between 0.1 and 0.5 mm and is also very important to achieve osteo-integration. The CCD angle is 135°. The stem is straight and can be implanted indifferently in any degree of ante- or retro-version thus being indicated in dysplastic arthritis where we need to correct ante version.

Between 1993 and 1998 the Senior Author (RB) has implanted 92 consecutive cone stems in 88 patients with dysplastic arthritis. The acetabular component was always cementless and in Titanium. The articulating surface was Metal-on-Metal. The average follow-up was 10.1 years.

According to the Hartofilakidis classification we had 63 patients of type A, 18 of type B and 11 of type C. Clinically we had 89% of satisfactory results with no cases of anterior thigh pain. No patient required revision of the stem, while we revised a cup in Group C.

Radiographically, 17% of patients showed some resorption in femoral zone 1 and 7. In 12 cases it was a narrow fissure due to the oscillations of proximal stem under load. This lesion was never progressive. In the same zones we observed 4 cases of real osteolysis. No radiolucent line was observed in other femoral zones. In the acetabular side we had 13 cases (14%) of radiolucency.

Cone stem gave excellent clinico-radiographical results in dysplastic arthritis.

A1-3

CHARACTERISITICS OF THE FEMORAL GEOMETRY OF DEVELOPMENTAL DYSPLASTIC HIPS AND THE SURGICAL STRATEGY –FROM THE TREATMENT OF JAPANESE ARTHRITIC HIPS WITH LATERALFLARE STEMS

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Although developmental dysplastic hip (DDH) is well recognized as an etiology for osteoarthritis, it is globally not so common. However in Japan, it is the most popular etiology. It is estimated more than 90%. To obtain a stable and sustainable cementless stem fixation, high proximal fit-and-fill and closer reproduction of physiological load transfer mechanism are very important. So knowing the characteristics of DDH femur is very important.

Morscher divided the femur into 2 parts at inter-trochanteric line and described the relation only between each axis to describe and to explain the aberrations of neck-shaft angles and anteversions. According to this definition, femurs of DDH are described to have bigger ante version and bigger neck-shaft angle. This sounds that standard high fit-and-fill stems are not available for DDH. So several makers have stems with different medial curve. But in our experience we have scarcely chosen non standard curve stems retrospectively.

Since 1989 we have been developing high proximal fit-and-fill cementless stem with lateralflare. First it was implemented to custom stems and later it was implemented to off-the-shelf (OTS) stems. Since 2001 the OTS stems became in service in Japan. We had to be very nervous about the availability for DDH cases; we had done 3D computer preoperative planning for each case. As its result, our OTS stems fitted to almost all cases.

MATERIALS AND METHODS

For further understanding of this result 195 whole femurs' CAT scan data were analyzed by the 3D preoperative planning system. First DDH cases which the centers of the femoral heads are easily determined were extracted. Virtual stem insertions were performed. Then very good fit-and-fill is obtained for all cases. It meant that the general geometry of the proximal femur as long as the stem reaches is not different. Then all of the 195 femurs were assessed.

RESULT

The proximal femurs of the DDH cases have normal geometry with world standard femurs. They are twisted around the mid diaphysis in average 30.9 degree to the posterior condylar line. When they are twisted back, the average neck-shaft angle is assessed as 131.5 degree. We have also found that among the DDH cases with severe ante version, some cases had grown their capital and acetabular osteophytes to posterior direction then the mechanical center of the femoral head in axial plane was posteriorly adjusted. It means that excessive ante version was reduced automatically. But in other cases the osteophytes had grown keeping the same ante version. In some cases, even proximal femur seemed to have high ante version and appeared to be only external rotated contracture when the knee also observed. So our strategy for DDH case is; performing 3D preoperative planning at least to the knee if possible to the ankle, if the OTS stem can fit and reproduce original hip center we use OTS stem. If we found self ante version adjustment custom stem with ante version modification is used. If we found difficulty in OTS stem & canal fitting, we also make custom stem.

A1-4

2-18 YEAR RESULTS IN CDH TOTAL HIP REPLACEMENTS

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INTRODUCTION AND AIMS

Congenital hip dislocation still occurs. In Type I the acetabulum is dysplastic but there is reasonable coverage. In Type II the outer roof is missing and bone graft is required. In Type III a false socket is present and in Type IV there is no or minimal contact present.

METHOD

Results of 262 CDH cases with a follow up of two to eighteen years were reviewed. The device used was a proximally modular stem/sleeve cementless SROM stem.

Type I required no grafting. Type II required roof grafting and on two occasions the use of an oblong socket. Type III cases were brought down to the true socket except in the elderly. Type IV cases were returned to the true socket and all required a subtrochanteric shortening osteotomy.

RESULTS

Type I have the same results as simple primary osteoarthritis. Type 11 and type 3 have not had any significant problems.

The only significant problems were in the type four cases.

In sixteen of these cases there have been three non-unions, two of which resolved with further treatment (bone grafting and long stem revision) and one remains asymptomatic. One case of avascular necrosis at the proximal segment occurred requiring the use of a structural allograph and revision to a long stem. In three the proximal segment split at index surgery. They were treated with circlage wires. This method of fixation proved inadequate resulting in stem substance requiring revision. We now recommend cable and or cable plates should this occur.

CONCLUSION

In light of this significant complication rate, probably as a result of avascularity of the proximal segment due to muscle release in an attempt to gain length, some further thought and discussion is obviously required. It might be preferable to sacrifice length in order to preserve the vascularity of the proximal segment.

A2-1

MODEL-BASED RSA OF A HIP STEM USING GEOMETRICAL SHAPE MODELS

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Roentgen stereophotogrammetry (RSA) is a highly accurate three-dimensional (3-D) measuring technique for assessing micromotion of orthopaedic implants. To facilitate accurate measurements, at least three noncollinear spherical tantalum markers must be inserted in the host bone and attached to the implant. Because of regulatory issues, attaching markers to implants is a difficult and tedious task. One alternative that does not rely on attached implant markers involves creating a surface model of the implant. Another alternative to attached markers is the use of elementary geometrical shapes (EGS) (eg, straight lines, spheres, circles, and cones) to create a representation of the implant. The EGS model-based RSA technique might not be used for implants that have more complex shapes, such as femoral components in total knee arthroplasty.

The aim of our study was to validate and compare two different model-based RSA techniques (model-based RSA using surface models, and model-based RSA using elementary geometrical shape (EGS) models) to determine micromotion of a commercially available hip stem. We assessed if model-based RSA techniques were an accurate alternative for marker-based RSA.

The two model-based RSA methods were validated by an in vitro phantom experiment and compared in an in vivo experiment. Laser scanning was used to produce reverse engineered models for each implant size.

We tested two stems simultaneously during an in vitro validation experiment. One stem was marked with three spherical tantalum markers. Each stem had a 28 mm head attached and was rigidly fixed in a sawbone with eight tantalum markers attached at clinically representative locations. Twelve RSA radiographs were obtained in random, clinically relevant orientations. Migration was measured between the component and the bone using standard marker-based RSA (as a reference) and both model-based RSA techniques. There was no change in relative pose between the component and the markers in the sawbone, so for successive RSA radiographs, the mean of the calculated migrations measured the systematic algorithm errors. The standard deviation (SD) of the calculated migrations measured the accuracy of zero motion, or precision of the RSA algorithm.

The in vivo experiment was done with 19 RSA examinations of seven patients from a historical cohort. We calculated the migration between the model of the hip stem and the three markers attached to the hip stem. Because the motion between the implant and its attached markers was zero, the mean and standard deviation provide information about the accuracy and precision of the RSA algorithm.

The phantom experiment showed that the accuracy of model-based RSA using surface models is the same as the accuracy of marker-based RSA, however, the precision is lower than the precision of marker-based RSA. No significant differences in accuracy and precision were found between the EGS model-based RSA algorithm and marker-based RSA. In contrast to the results from the phantom experiment, the clinical data did not show large differences between the two model-based RSA algorithms.

Main advantage of EGS model-based RSA compared with model-based RSA using surface models is that in EGS model-based RSA there is no difference in shape between the model and component.

We are convinced that both model-based RSA algorithms are a possible replacement for marker-based RSA. However, because of its higher precision, for this hip stem, EGS model-based RSA provides the best alternative for marker-based RSA.

A2-2

DISLOCATION RATE IN LARGE DIAMETER METAL-ON-METAL HIP REPLACEMENT

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A. INTRODUCTION

Dislocation rates with total hip arthroplasty vary from 3% to 15%. Poor muscle tone contributes to hip instability in older patients while increased range of movement demands in active young patients can also make them prone to dislocations. Dislocation rates in large headed metal-on-metal resurfacings are extremely low. However, many patients are unsuitable for resurfacing and need a replacement. In such cases, it is attractive to transfer the large-headed metal-metal bearing advantage to replacement arthroplasty in order to reduce wear and dislocation rates. This study seeks to answer the question if large diameter metal-metal total hip replacement reduces early dislocation rate?

B. MATERIALS AND METHODS

Two hundred and six consecutive primary metal-metal THRs (189 patients) were included. The device consists of an uncemented cup, a matching modular cobalt chrome head (head diameter ranged 38 - 58mm) fixed on a stem through a 12/14 cone. Cemented stems were used in 107 procedures and 99 were proximal-porous uncemented stems.

Age at operation ranged from 37 to 83 years. Thirty patients were 55 years or under, eightyone were 56 - 65 years and ninetyfive were over 65 years. There were 122 females and 67 males. Posterior approach was used in all.

C. RESULTS

There were no dislocations in these 206 consecutive procedures.

D. DISCUSSION AND CONCLUSIONS

Metal-metal hips have lower dislocation rates than hips containing polyethylene (0.9% against 6.4% in a matched series). This is attributed to the suction-fit effect of metal-metal bearings. Large diameter bearings have the additional benefit of having to translate a greater jump distance before a dislocation. This dual advantage leading to extremely low dislocation rates was first noted in metal-metal resurfacings. In large headed metal-metal THRs, the head-neck ratio is even more favourable and these devices appear to eliminate early dislocation as a major complication.

A2-3

CONTROLLED RESTORATION OF HIP MECHANICS IN THA

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INTRODUCTION

THA continues to improve but complications still occur. Dislocation continues to be a significant problem, along with wear debris resulting in lysis. Weakness of the abductor muscles due to improper reconstruction can be a contributing factor for both of these complications. As a result we see a number of trends trying to address these concerns (hard-on-hard-bearings, big heads, increased use of constrained sockets, and use of expensive surgical navigation). Proper reconstruction of the joint mechanics has demonstrated reduced incidence of these complications, however, intra-operative application can be challenging.

METHODS

To study the influence of implant geometry on tissue balancing and joint stability, the authors selected a stem design that permits independent selection of lateral offset, version and leg length. This study presents results on 957 stems implanted since 2001.

842 were primary and 115 were revision cases. All were performed using the posterior approach. Acetabular implants were from a variety of manufactures and variety of bearing surfaces. All cases were cementless. Data on stem, neck and head selection were available on 800. Head centers were plotted in bubble chart.

RESULTS

Data clearly showed that a wide variety of offsets and lengths are required to properly balance the soft tissues. It was also clear that there is little correlation between head center and stem size.

DISCUSSION

The head location data suggest that hip joint reconstruction benefits from the availability of many head centers for every stem size. This data should be helpful in determining stem selection for THA.

A2-4

THREE DIMENSIONAL ANALYSIS OF RANGE OF MOTION AND VIRTUAL DEBRIDEMENT IN PATIENTS WITH FEMORO-ACETABULAR IMPINGEMENT

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Femoro-acetabular Impingement is a leading cause of early osteoarthritis in the young patient. The pathomechanism is characterized by a repetitive abnormal contact between the acetabular rim and the femoral head-neck junction. Two different types of bony deformities have been characterized as „cam"-type or „pincer"-type impingement. "Cam"-type impingement results from an aspheric configuration of the femoral head-neck junction. "Pincer"-type impingement is caused by retroversion of the acetabulum or overcoverage of the femoral head (coxa profunda). Combinations of both types are frequent.

A computer-assisted, non-invasive method has been developed to analyze hips with FAI and perform virtual debridement of the joint. The method allows for individual hip motion to be simulated, locations of impingement to be identified and the collision results to be calculated. The system also enables the examiner to perform virtual debridement of the acetabular rim, the femoral head-neck junction, or both. In a clinical pilot study we analyzed 36 patients with normal hips as a control group against 24 patients (26 hips) with FAI. Impingement zones were detected and ROM was simulated using a 3D model of the pelvis and femur calculated from CT data. ROM of both groups was compared. After the method had proven its reliability, we started to compare the improvement of ROM after virtual debridement with the improvement of ROM measured with a navigation system in real-time surgical dislocation. 4 patients were investigated so far.

In the pilot study findings were significant. Patients with FAI had a mean flexion of 104 ± 16.1° versus 121 ± 11.8° in the control ($p < 0.001$). Internal Rotation in 90° flexion was also significantly reduced (10 ± 6.8 vs. 35 ± 12; $p < 0.001$). Findings in the sequel study are preliminary results. The simulated range of motion in the 4 patients correlated well with the results from surgical navigation regarding the improvement. However the study group is yet too small to calculate significant findings and future results have to be awaited.

Our method has proven to be an accurate and reliable means of assessing range of motion of the hip and of identifying impingement zones in patients with FAI. The identification and localization of the impingement zones and the three-dimensional visualization may qualify our method as an accurate method of supporting and facilitating preoperative planning for surgical debridement. Prediction of benefit of ROM shows a promising trend. However, the use of HipMotion also has restrictions. It is not applicable for end-stage osteoarthritic hips with bone on bone contact creating an intraarticular impingement and for largely dysplastic hips with a shallow acetabulum having an additional translational next to the rotational component, making it impossible to define a center of rotation.

A2-5

EFFECTS OF GEOMETRY OF THE FEMORAL COMPONENT ON THE IMPACT FORCE AND INTRAOPERATIVE FRACTURE DURING THA

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PURPOSE

The purpose of this study was to investigate the relationship among the geometry of femoral components, impact force of femoral components and potential of intraoperative fracture of proximal femur in cementless THA.

MATERIALS AND METHODS

Preoperatively, the bone-mineral density of the proximal femur was measured by dual-energy x-ray absorptiometry to determine the bone quality. Two types of femoral components, a short double-wedge type in 20 patients (group S) and long conventional type in 20 patients (group L), were implanted by the same surgeon in this study. To measure the impact force, we developed an impactor attached with strain gauges. The impact force was measured at rasping, trial and final seating times during THA.

RESULTS

No significant differences in the bone-mineral density was detected between both groups. The impact force at rasping, trial, and final seating times was averaged 2241.9 N, 1716.9 N, 1409.2 N in the group S and 1508.9 N, 1729.7 N, 1570.6 N in the group L respectively. The impact force in the group S was larger than that in the group L at the rasping time ($P < 0.05$). Intraoperative fracture of Vancouver type 2 occurred in 4 patients in the group S and none in the group L during rasping. The impact force of the patients with fracture at rasping time was significantly larger than that of the remaining patients in the group S ($P < 0.05$).

CONCLUSION

The geometry of the femoral component seems to have relationships with the impact force and intraoperative fracture.

KEY WORDS: Total Hip Arthroplasty impact force intraoperative fracture

A2-6

THE EFFECTS OF COMPONENT POSITIONING ON BONY IMPINGEMENT IN TOTAL HIP ARTHROPLASTY

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PURPOSE

Component and bony impingement in total hip arthroplasty (THA) is a common cause of hip dislocation. The variables that affect component impingement have been well defined; however many of the variables that affect bony impingement have not been studied. The purpose of this study is to evaluate the effects of translational movement of the acetabular component, osteophyte removal, head and neck length, and femoral ante version on bony impingement in total hip arthroplasty.

METHODS

The hip range of motion (ROM) of ten THA patient with osteoarthritis was modeled using their pre-operative pelvic computer tomography scans and the HipNav software (CASurgica, Inc, Pittsburgh, PA). Each hip model was subjected to twelve series of simulated ROMs. In the first six series, the acetabular osteophytes were removed. In the first three series, the acetabular component was translated in two mm increments in the medial/lateral, superior/inferior, and anterior/posterior directions. The fourth series changed the femoral ante version in five degree increments. The fifth and sixth series varied the femoral head length and simulated offset acetabular liners. The last six series repeated the first 6 series without osteophyte removal. The component impingement was modeled for a 28 mm head and compared to the bony impingement.

For each series of simulated reconstructions, the maximum internal and external rotation was calculated in 10 degree increments of hip flexion. In addition, the maximum flexion, extension, and internal rotation with different adduction angles were calculated. When component impingement occurred before bony impingement, the cup abduction and version were changed to allow the motion to continue until bony impingement occurred and that number was recorded for bony impingement.

RESULTS

Bony impingement occurs in progressively lower degrees of motion as the acetabular shell is translated medially and superiorly. Each millimeter of medial translation decreased the internal rotation before bony impingement by 1.5° to 2° degrees, depending on the amount of flexion tested. Each millimeter of superior translation decreased the internal rotation by 0.6° to 1.9° degrees. Each degree of femoral ante version increased internal rotation by 1.2° to 1.7° degrees and decreased external rotation by 0.8° to 1.2° degrees. Each additional millimeter of head or neck length increased internal rotation by approximately 1° degree. These results were even more dramatic when the osteophytes were not removed. The degree of internal rotation before both bony and component impingement decreased as the hip was progressively flexed or adducted. At hip flexion greater than 60°, the greater trochanter impinged against the ilium with internal rotation, whereas below 50° of flexion, the greater trochanter avoided the ilium and ultimately impinged on the pubis.

DISCUSSION

To our knowledge, this research is the first study to establish the limitations of hip range of motion from bony impingement irrespective of component impingement and to evaluate in detail the variables that influence bony impingement. With larger diameter heads, component impingement becomes less important and bony impingement may limit hip range of motion. Medial and superior translation of the acetabular shell, osteophyte retention, short head/neck length, and abnormal femoral ante version all adversely limits the hip ROM before bony impingement. This decreased motion is even more pronounced when the osteophytes are not removed. Whether bony or component impingement occurs first depends on the abduction angle and ante version of the acetabular implant, head/neck ratio, amount of cup translation, and osteophyte removal. Femoral ante version was found to impact both component and bony impingement; thus, changing the femoral ante version to accommodate a poorly oriented acetabular component could lead to increased bony impingement.

A2-7

IN VIVO ASSESSMENT OF HIP JOINT KINEMATICS FOR VARIABLE BEARING SURFACES USING FLUOROSCOPY, ACCELEROMETER AND SOUND SENSORS

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The objective of this study was to evaluate the kinematics for subjects having a THA having various bearing surfaces using fluoroscopy, accelerometers and sound sensors. Subjects entered in the study had one of the following bearing surface interfaces; metal-on-polyethylene, metal-on-metal, ceramic-on-polyethylene, and ceramic-on-ceramic. All subjects evaluated were implanted with a press-fit THA. Patient selection was done by mobility, implant, and recommendation from the surgeon. All THA subjects were implanted by one surgeons and were judged clinically successful (Harris hip scores >90.0). The subjects were asked to perform gait on a treadmill and then on a force-plate, while under fluoroscopy surveillance. Initially, in vivo kinematics were determined using fluoroscopy and our three-dimensional model-fitting technique and the results were compared using subject specific data and for each bearing surface material. Tri-axial accelerometers were attached to the greater trochanter and the pelvis to determine propagating frequencies across the hip joint, allowing for the determination of transfer functions. A sound sensor was also attached to the hip joint to determine if sound could be correlated with the incidence of hip separation. The fluoroscopic videos were evaluated during stance and swing phases of gait. The force from the force plate and the fluoroscopy video were synchronized and analyzed during one full cycle of gait. The ground reaction forces of the force plate and the kinematics obtained from the fluoroscopy analysis were compared.

Early results from this study revealed that the kinematic patterns demonstrated distinct differences between the various bearing surfaces. The sound and accelerometer results for each patient group differed in magnitude and pattern. Interestingly was the distinct correlation of a high frequency sound occurring at the time of hip separation. As the femoral component impacted the acetabular cup, the sound sensor revealed a high frequency sound. Results from this study may give researchers and implant developers a better understanding of kinematics around the hip joint and how they vary with respect to different THA bearing materials. The comparison of the variable bearing surfaces will enable improvements in future implant development. Further analysis is being conducted on more subjects before definitive conclusion can be made.

A3-1

EXCELLENT MID-TERM RESULTS WITH TAPERED MODULAR CONICAL STEMS FOR FEMORAL REVISION WITH SEVERE BONE STOCK LOSS

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Long-term results obtained with the conical tapered stem designed by Wagner for cementless hip revision were on the whole very encouraging. Neverthless we have identified some defects of the stem such as an excessive valgus neck, an insufficient offset for larger stems and a lack of modularity, making soft tissues tension sometimes difficult.

The T3 stem was designed with the purpose of correcting these defects. The T3 stem is made of Titanium alloy with a textured surface finish and is modular. The lateral offset has been increased to 42 mm (34 mm for Wagner's stem) and the cervico-diaphyseal angle has been reduced from 145° to 138° degrees. Recently, the T3 stem has been substituted by the Restoration having a more varus neck (132° instead of 138°) and 3 sizes of distal stem (instead of 2). In this retrospective study we have analized the preliminary results obtained with the T3 stem.

We reviewed the first 30 consecutive cases having an average FU of 6.2 years (range 4.7 - 8 years).

We have always used a trans-femoral approach with "prophylactic" distal cable circlage. In no case an homologous bone graft was used. 90% of the cases were rated Excellent or Good. No re-revision was necessary. 87% of the femurs showed good bone reconstruction and 24% some subsidence (only two cases >1 cm) without clinical symptoms except for the necessity of a compensatory heel pad.

Distal fixation stems like T3 are the implants of choice for severe bone stock loss (Paprosky 2C-3) for their immediate mechanical stability allowing early weight bearing. Transfemoral approach allows complete removal of debris and scar tissue, enhancing bone reconstruction.

A3-2

MICROMOTION AND INTERFACIAL GAPS BETWEEN FEMUR AND CEMENTLESS STEM: FINITE ELEMENT MODELS

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BACKGROUND

In a cementless total hip arthroplasty, interfacial gaps between a femur and a stem can be occurred due to an inaccurate femoral canal shaping. Recent literatures reported that 60% to 43% of stem surface contact with the bone. Such interfacial gaps will not only deter successful bone ingrowths at the sites but also increase the relative motions of the stem to the bone increasing the possibility of the stem loosening. Thus a quantitative analysis of the effect of the interfacial gaps on the micromotion is required to find a clinically allowable threshold on the amount of the interfacial gaps, as well as to identify the critical position where direct stem-bone contact should be acquired.

OBJECTIVE

To find relation of the micromotion with the position and the size of interfacial gaps.

METHODS

FE models with interfacial gaps which simulate the micromotion of the Zimmer Versys Fibermetal tapered stem under stair climbing load were built. To locate the position on the stem surface where the existence of the interfacial gap have most significant effect on the micromotion, 500 FE models with randomly placed interfacial gaps were simulated. Also, 17 FE models with variable amount of the interfacial gaps at the experimentally observed locations were simulated to find the effect of the size of the gaps.

RESULTS

For the stem, existence of the interfacial gaps in Gruen zone 7(proximal medial surface) and zone 8(proximal anterior surface) affected the micromotion most significantly; when the interfacial gaps existed at the both surfaces, micromotion increased to 417% of that without interfacial gaps. Also, micromotion increased with wider interfacial gaps. With no interfacial gap, FE model expected 21.4□m of micromotion. Then micromotion increased linearly (0.24□m/%, r^2=0.99) until the gaps cover 70% of stem surface. But the micromotion increased nonlinearly after that point. However, when the gaps covered more than 70% of stem surface, 88% FE models with randomly placed gaps showed higher micromotion than FE models with gaps at the experimental locations.

CONCLUSION

To achieve good initial stability, more caution should be paid to obtain direct bone-stem contact at the proximal medial and anterior surfaces. Also, interfacial gaps should be kept under 70% of stem surface to minimize the possibility of instability of the cementless femoral stem.

A3-3

NEW GENERATION OF ISOELASTIC FEMORAL STEM PROSTHESIS – INTERMEDIATE-TERM FOLLOW-UP

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Preventing stress shielding remains one of the main goals in modern prosthetic stem construction. Contemporary scientific achievements made it possible due to new materials and new prosthetic designs, one of which is the PhysioLogic stem invented by Dr. Robert Mathys.

The aim of our work was clinical progress observation and retrospective analysis after implanting new generation of isoelastic femoral stem prosthesis - PhysioLogic stem

The PhysioLogic is a composite prosthesis consisting of a titanium core sheathed in implantable PEEK polymer and additionally coated with a titanium layer. Firstly, its design is such that the elasticity under bending load of the stem corresponds closely to that of natural bone, enabling a gradual load transfer from the stem to the surrounding bone. Secondly, the titanium coating of the stem promotes a rapid osteointegration.

From 1997 to 2001 we have performed 59 implantations of PhysioLogic stem (53 primary and 6 revision operations). The patients included 35 men and 24 women who had a mean age of forty-five years (range, twenty-one to sixty-nine years) at the time of the surgical treatment. The indications for total hip replacement were osteoarthritis (21), hip dysplasia (14), rheumatoid arthritis (10), femoral neck nonunions (6), femoral stem instability (4), bone tumors (2) and second stage of revision procedure after infected complications (2). In 57 patients we used totally uncemented systems (poly RM cup coated with titanium – 49 patients and metal-metal RM cup -8), in 2 patients – hybrid fixation (cemented Muller reinforcement ring). All implants were produced by Mathys-Medical, Switzerland.

Radiolucent lines in each of the three acetabular zones described by DeLee and Charnley (1976) were measured on standard anteroposterior and lateral radiographs of the hip. Fixation of the femoral component was evaluated in accordance with the categories of loosening described by Harris et al.,1982. Clinical and functional results were evaluated by Harris Hip Score. Bone density in Gruen's and Charnley's zones was measured by Densitometer Norland XR 46 additionally. Follow-up period was 4-8 years (average 6,5). Postoperatively, the patients were evaluated at three months, six months, one year, and two years after the operation and then on a regularly scheduled basis thereafter.

The average Harris hip score has improved from 40 points (range, 27 to 48) to 93 (range, 89 to 95) at final follow- up. We evaluated the bone-ingrown fixation of all the stems - there was no aseptic loosening. After 4-8 years we observed very good results according to the Gruen score – 19 (range, 17 to 21). In two cases we had late postoperative infected complication (after 1,5 years): first– revision after infection, second– rheumatoid arthritis. In second patient we removed well fixing stem with signs of good bone integration.

The results of our study don't let us make any absolute statements yet, but it is obvious that the behavior of the PhysioLogic stem is very attractive.

A3-4

JACK AND THE BEANSTALK OR THE USE OF LONG STEMS IN PRIMARY TOTAL HIP REPLACEMENTS

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INTRODUCTION AND AIMS

Large diameter canals necessitates the use of large stems, which risk end of stem pain if a short stem is used, especially if the stem is greater than 19 mm. A long stem diffuses the bending stress over a longer distance and hence end of stem pain is very unusual.

METHOD

The senior author has thirty-six cases with a mean follow up of five years. The stems used were the SROM proximally modular stem/sleeve non-cemented system. The reason for use in three was giants (one ft. taller than senior surgeon 5'8"), giant canals (>19mm) in four, femoral deformity in twelve and a variety of other conditions including disproportion (2 sizes dia. difference between AP & Lat X-ray) and a short isthmus (<3cm). A long stem was also used in one case of osteogenesis imperfecta.

RESULTS

Three distal femoral longituatal crack fractures occurred during stem insertion. Two bilateral, in one case femoral deformity necessitated the use of a long straight stem, which is very usual. All were treated successfully with wires and/or cable plates. No case has end of stem pain. Two stems loosened, one in the osteogenesis case, which was treated with structural allograph and standard cemented stem. One failure of union of a subtrochanteric osteotomy resulted in subsidence and loosing requiring revision to longer calcar replacement stem. The other patients have done well and the senior author is encouraged to continue with this practice in these usual and difficult cases.

CONCLUSION

In disproportion, i.e. where the canal is significantly oval as opposed to round and in short isthmus cases, obtaining distal stability with a short stem is difficult. A long stem improves fixation. In osteogenesis imperfecta spreading the load over a longer distance is helpful.

A3-5

LATERAL FLARE CUSTOMIZED UNCEMENTED STEMS IN PATIENTS YOUNGER THAN 55 YEARS OF AGE: A 6 TO 12 YEAR PROSPECTIVE STUDY

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BACKGROUND

First generation uncemented stems for THA were associated with high rates of thigh pain, aseptic loosening and stress shielding. To minimize these problems a high metaphyseal loading femoral stem that incorporates a lateral flare in the proximal body was designed and initially available as a custom implant.

MATERIALS AND METHODS

35 consecutive patients (40 hips) younger than 55 years of age (average 45.2 years, range: 30 to 55 years) were prospectively followed for an average of 9.2 years (range 5.7 to 12.2 years). All patients received a customized lateral flare cementless femoral stem designed to provide a high metaphyseal fit in the proximal femur. The preoperative diagnoses included primary osteoarthritis in nine patients, avascular necrosis in sixteen patients, congenital hip dysplasia in seven patients and secondary osteoarthritis due to slipped capital femoral epiphysis in three patients. Clinical evaluations were performed before the operation, three, six and twelve months after the surgery; and yearly thereafter utilizing the Harris Hip Score (HHS)[24]. Anteroposterior and lateral films of the involved hip as well as anteroposterior view of the pelvis were assessed along with clinical follow-ups. Immediate postoperative and last follow-up x-rays were evaluated and rated by a qualified orthopedic surgeon from another academic institution who was blinded to the clinical results. The stems were rated for stability, and the presence of osteolysis, progressive radiolucent lines, stress shielding, bone resorption, cancellous or cortical thickening and visible periprosthetic bone density changes was recorded. The distance from the tip of the greater trochanter to a reproducible reference point on the stem was used to measure axial migration of the stem.

RESULTS

There was one patient with aseptic loosening of the stem and one patient with late deep infection necessitating subsequent revisions. The mean preoperative Harris hip score was 47 and 97 at the latest follow-up. The mean axial migration was 0.51 mm, femoral osteolysis was found to be circumscribed to the proximal femur in Gruen zones 1 (15%) and 7 (7.5%) in patients with accelerated polyethylene wear. Radiographic changes consistent with new bone apposition underneath the lateral flare of the stem in zone 2 as well as in zones 6 and 7 were found in 72.5% of the cases.

CONCLUSIONS

This study demonstrated that a custom lateral flare stem for primary arthroplasty in the young patient population achieves excellent clinical results with low rates of aseptic loosening.

De Santis Award

A4-1

VANCOMYCIN STABLY AND PERMANENTLY BONDED TO IMPLANT INHIBITS BACTERIAL SURFACE COLONIZATION AND INFECTION DEVELOPMENT

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To combat implant-associated infection, we have permanently derivatized an implant surface with antibiotics to prevent bacterial colonization while fostering new bone ingrowth. Using this novel technology, vancomycin was coupled to Ti alloy via silane and Fmoc chemistry. Based on immunohistochemistry, vancomycin covered the surface uniformly and remained stable over time when exposed to physiological environments and bacterial cultures. The surface was potently bactericidal and inhibited colonization by both S. aureus and S. epidermidis. Using scanning electron microscopy, extensive biofilm formation is observed on control untreated surfaces, while no biofilm is seen on the TI-VAN. Osteocompatibility of the implant was evaluated by seeding the surface with MC3T3-E1 pre-osteoblasts. Cell numbers on both surfaces were comparable and the cells retained their normal morphology and organization. Finally, the surfaces were tested in animal models of bone infection and periprosthetic infection where they inhibited bacterial colonization of the orthopaedic rod. Based on its osteocompatibility, microbicidal properties and stability, this antibiotic-modified surface is a first step towards engineering biologically active implants that are permissive to new bone growth in an infection-free environment.

A4-2

GOOD LONGEVITY, GOOD FUNCTION, WHAT WILL THE TECHNOLOGISTS DO ABOUT THR INFECTION?

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INTRODUCTION

Modern designs in total hip replacement (THR) have the goal of improving longevity through better fixation (design) and less wear (design and materials). Recent advances and patient demand have spurned a new generation of THR designs with better "function" for younger and more active patients. If this goal is realized, most current and future THR revisions will be due in large part to infection. This paper presents data on the frequency and typical causes of this mode of failure/weakness in THR surgery.

MATERIALS AND METHODS

A retrospective review was completed examining the causes of failure (revision) in THR. The series includes the senior author's consecutive series of primary THA's. The review sought demographic data, methods of fixation and modes of failure.

RESULTS

The study involved 1900 primary THA's. The average age of the patient was 62 years old. There were 90 revision THA's in this group. The most common causes of revision were:

Polyethylene wear	30
Osteolysis	20
Periprosthetic fracture	15
Instability	13
Infection	12

Of these factors, technology has modified/improved wear characteristics of THA and ultimately osteolysis. Of the remaining etiologies of revision, computer aided surgery will help the surgeon decrease the incidence of instability as a possible source of revision. Therefore, infection remains as a prominent cause of revision in THA.

DISCUSSION AND CONCLUSIONS

Given resent advances in design, manufacturing and bearing surface, aseptic loosening and polyethylene wear may play a smaller role in revision. Of the remaining etiologies of revision, computer aided surgery will help the surgeon alleviate malalignment and instability as possible sources of revision. Better designs, porous metals and augments will help improve fixation even further, and make it even less significant as a failure mode.

Clinicians and biologists have focussed attention on the therapeutic treatment of THR infection, but little attention and progress appears to have been given to the "prevention" of infection. With the exception of anti-biotic impregnated bone cement, there appears limited fundamental breakthroughs from implant manufacturers on how to prevent THR infection. Technologists should focus attention and resources on developing infection resistant implant metallic surfaces, and/or smart surfaces which detect and respond to the onset of infection.

A4-3

DERMABOND EFFICACY IN COMPUTER ASSISTED TOTAL JOINT REPLACEMENT WOUNDS

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INTRODUCTION

Surgical wound health after total joint replacement (TJR) surgery is closely monitored for evidence of infection. Surgical wound closure directly effects superficial infection and possbily deep infection. High-viscosity Dermabond has been an effective alternative to conventional sutures or staples in other surgeries. Efficacy studies have been limited to incisions in low-tension dermal areas. The purpose of this study is to measure the efficacy of Dermabond in healing high-tension, mobile surgical sites of TJR in comparison to wound closure using staples.

METHODS

A single surgeon performed 223 primary total knee arthroplasty (TKA) since 2003. All subjects underwent computer assisted surgery (CAS) of which 1 was CT-Based and 222 were CT Free. In addition a single surgeon performed 193 primary total hip arthroplasty (THA) with 74 CT-Based CAS and 119 CT-Free CAS since 2002. THA approaches used were 180 posterior, 8 anterior, and 5 transtrochanteric. Dermabond and a 4-gauge subcuticular suture were used on 277 cases with knee incisions beginning May 2004 and cases with hip incisions beginning January 2004. 188 controls had wound closure using surgical staples. All wounds were prepared with Monocryl sutures for deep fascia and subcutaneous layers before using the case or control method. Variables analyzed at two-week and six-week follow-up include deep infection, superficial infection, skin abscess, abnormal redness, blisters, drainage, and dehiscence. Wound closure time was assessed for TKA procedures. Patients with history of diabetes, anemia, or rheumatoid arthritis were removed from the study.

RESULTS

The patient population includes 111 males, 166 females, mean age 64 years. Controls consist of 75 males and 113 females with an average age of 63. There were no reported deep infections. Following chi-square analysis, incidence of infection at two-week and six-week follow-up in Dermabond cases was statistically insignificant when compared to controls. Evidence of inflammatory response, i.e. overt redness, drainage and dehiscence showed no increase. Time to close in Dermabond TKA cases averaged 8 minutes longer than control subjects. However, incidence of blisters in Dermabond cases was significantly lower than controls.

CONCLUSION

Dermabond has been studied in many low-tension applications with relative efficacy. TJR surgery provides a medium of high-tension wound closure with a similar expectation of low infection rate. This study confirms Dermabond as an equal or superior tool in minimizing infection from incision site. The lack of statistical significance for an increase of acute inflammation and infection confirms Dermabond as an equal alternative to surgical staples in TJR wound closure and appearance. All blisters occurred on control subjects due to the adhesive tape administered to protect wounds with staples. This led to the statistical significance of tape blister abscess reduction. In addition, suture abscesses occurred in the control group. The time to close slightly increased operating room time due to the subcuticle suture layer. Less wound care without the use of tape, dressings, and suture care may lead to increased satisfaction in TJR patients. High-viscosity Dermabond represents an effective alternative to surgical staples for TJR incisions in a high-stress surgical environment.

A4-4

INFECTION-SPECIFIC BIOMARKERS IN THE SYNOVIAL FLUID

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INTRODUCTION

In a previous genomic study, analyzing the gene expression of synovial fluid leukocytes from TKA infection, we identified a target list of infection biomarkers. The purpose of this study is to test three of these biomarkers for infection with immunoassay.

METHODS

70 synovial fluid samples were prospectively collected at the time of total joint arthroplasty (TJA). 12 samples were from native joints at the time of TJA (controls), 14 samples were from TJA being treated for clear evidence of infection (infections), and 44 samples were from revision TJA (unknowns). Pertinent labs were collected including CRP, ESR, cell counts, and pathology. This study tested three biomarkers: interleukin-1-beta (cytokine); SKALP (antimicrobial peptide), and SLPI (antimicrobial peptide). Protein levels were measured in the synovial fluid by standard, commercially available immunoassay.

RESULTS

All twelve control samples had <10pg/ml IL1B and <1300pg/ml SKALP. All 14 infections had IL1B levels >50pg/ml (ave.5038pg/ml); 13 of 14 infections had SKALP levels above 1300pg/ml (ave. 2340pg/ml). Of the 44 revision TJA, only 9 had elevated IL1B and SKALP levels, and 7 of these cases had soft signs of infection such as broth only positive cultures. The SLPI protein was not a useful biomarker.

DISCUSSION

Based on information from genechip studies, we have identified infection specific biomarkers in the synovial fluid with rapid, inexpensive immunoassay. It appears that these biomarkers will help identify cases of occult infection; specific examples are presented. Future studies will test additional biomarkers and assess sensitivity and specificity in a larger population of patients.

A4-5

A NOVEL TECHNIQUE IN THE TREATMENT OF INFECTED TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

The treatment of periprosthetic infections (PPI) after total knee replacement (TKA) associated with bone destruction and massive loss usually includes removal of all prosthetic components, debridement of the joint, and insertion of antibiotic-impregnated cement spacer. This spacer offers no adequate mechanical support. To improve the mechanical stability, we present an alternative for filling the joint space and linked bones with a stable antibiotic-impregnated cement rod-spacer. The technique, its advantages, and the results over a 5-year period are presented.

METHODS

This rod-spacer can be custom-made at the time of surgery using Steinmann pins, any intramedullary nail, Rush rods, Harrington spine rods, bone cement (polymethylmethacrylate), and antibiotics. Three to six 40-gram packs of Palacos bone cement (Heraeus Kulzer GmbH, 61273 Wehrheim, Germany) with 2 grams of vancomycin and 2.4 grams of tobramycin per pack of cement are usually used. After all prosthetic components are removed and a meticulous debridement is done, the femoral and tibial intramedullary canals are reamed. A cylinder of antibiotic-impregnated cement is placed over the choused rod and well molded. While the cement is in the final stage of curing, the antibiotic-impregnated cement rod is placed within the intramedullary canal. As traction is maintained across the knee, extra antibiotic-impregnated cement is used to fill the space between the tibia and femur forming an antibiotic-impregnated cement rod-spacer in order to preserve length and improve stability. Adequately molding the antibiotic-impregnated cement rod-spacer allows a good soft tissue closure. A knee immobilizer is used for additional protection. Postoperatively, patients are allowed toe-touch weight bearing immediately ambulating with crutches or a walker. Patients are progressed to partial weight bearing with support over the ensuing 6 weeks. This technique was used in 9 (7 chronic and 2 acute) PPI cases over a 5-year period.

RESULTS

Four patients underwent a second stage TKA reimplantation with long stem femoral and tibial components. No bone graft was used in these patients. Patients were able to ambulate with crutches or a walker and were household or community ambulators in the time between the first and second stage. All four patients are doing well at an average follow up of 3 (1 to 5) years. Four patients ended up with a knee arthrodesis using long intramedullary nails. Two patients have a fusion confirmed radiologically. They are doing well at 3 years follow up. Two patients are in process of arthrodesis healing. An eighty-five years old patient has chosen the antibiotic-impregnated cement rod-spacer as definitive treatment option.

CONCLUSION

We present a new option for treatment of PPI after TKA associated with bone destruction and massive loss using an antibiotic-impregnated cement rod-spacer. This rod-spacer does not only provide stable fixation across the knee and local antibiotic delivery, but it has also a beneficial role in maintaining the joint space and preservation of soft tissue tension around the joint due to enhanced stability and length maintaining advantage. It improves the quality of life of the patients during the treatment allowing rapid mobilization and a higher functional level.

A5-1

POLYETHYLENE CONTACT STRESSES AFTER TOTAL KNEE ARTHROPLASTY COMPUTED IN VIVO

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Stresses at the bearing surface are a major factor in polyethylene wear and fatigue and affect the life of the implant. To date polyethylene contact stresses have been calculated using computational models and have been measured in vitro with pressure sensors. The tibial forces used to calculate contact stresses in these reports have been mathematical estimates. In this study, we measured tibial forces and knee kinematics in vivo and calculated contact stresses for activities of daily living.

A 68-kg, 80-year-old male was implanted with a tibial prosthesis instrumented with force transducers, a power induction coil, a microtransmitter, and an antenna (D'Lima et al, J Arthroplasty, 2005). The total axial load and the location of center of pressure were measured. An external coil was used to generate power in the internal coil, which powered the force transducers and the microtransmitter. Tibial forces were recorded for level walking, stair climbing, kneeling, and deep knee bend (lunge) activities. Knee kinematics were measured using a validated fluoroscopic analysis technique (Banks et al, IEEE Trans Biomed Eng, 1996).

The femoral component and tibial tray were modeled as rigid bodies. The insert was composed of tetrahedral elements with a mean edge length of 2 mm. Polyethylene was modeled as a nonlinear elastic material (D'Lima et al, World Biomaterials Congress, 2000). The orientation of the femur relative to the tibia for each activity was obtained from fluoroscopic motion analysis data. The magnitude and location of the tibial axial force were obtained from the measured tibial force for each instant in time. Peak contact stresses were computed in dynamic mode for one entire cycle of level walking and stair climbing and in static mode for the high flexion activities.

Peak axial loads averaged 2.3 times body weight (xBW) for treadmill walking. Contact stresses peaked at 27 MPa during heel strike and at 25 MPa during toe off. Peak contact stresses at maximum flexion angle during the swing phase were 15 MPa. The stresses calculated for these activities were within the range of those previously predicted. Peak axial loads were higher (3.6xBW) for stair ascent and contact stresses were concomitantly raised compared to walking. However, contact stresses were higher at maximum flexion (42 MPa) rather than at maximum load (40 MPa), which suggested that knee flexion angle had a substantial effect on contact stresses.

The patient was able to achieve up to 133° of active flexion (recorded fluoroscopically) between the tibial and femoral components for the high flexion activities. Since the tibial tray was implanted at a 5° posterior slope, the anatomic knee flexion angle achieved was 138°. Peak stresses were relatively higher due to the small contact area between the posterior rims of the femoral condyles and the insert: reaching 33 MPa for kneeling and 53 MPa for the lunge activity.

Combining in vivo measurement of tibial forces with accurate fluoroscopic kinematics is a powerful tool providing valuable insight into knee kinetics, performance, and wear.

A5-2

EFFECT OF SAMPLING RATE ON IN VIVO KINEMATIC ANALYSIS OF TOTAL KNEE ARTHROPLASTY IN DEEP KNEE BENDING MOTION

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Recently the 2D/3D registration technique with a computer assisted design (CAD) model of the implant has become a useful tool for examination in vivo kinematics of total knee arthroplasty (TKA). The purpose of this study is to investigate the proper sampling rate for the analysis of in vivo kinematics of deep knee bending motion after TKA. Five cruciate retaining (NexGen CR) and five posterior stabilized (NexGen LPS-Flex) TKA fluoroscopic images were analyzed with four sampling rate conditions as follows; group 1: all images, group 2: every 10 degrees, group 3: every 30 degrees, group 4: two frames (full extension and full flexion). Mean axial rotation of the femoral component was 15.0°±1.7, 13.6 °±2.4, 11.0°±2.4, and 9.9°±2.7 respectively in CR TKA, and 14.0°±6.6, 12.8°±7.0, 11.2°±6.6, and 7.1°±3.2 respectively in PS TKA. There was a significant difference between group 2 and 4 ($p<0.05$). As for the kinematic pathway of the pivot pattern, group 1 and 2 revealed a lateral pivot pattern during mid-flexion, however, group 4 revealed a medial pivot pattern in all TKAs. In anterior/posterior (A/P) translation of the femoral condyle centers, mean medial A/P translation was 12.2mm±2.8, 10.9mm±2.5, 9.2mm±3.1, and 6.3mm±1.7 respectively in CR TKAs and 10.6mm±0.6, 9.4mm±1.5, 6.9mm±1.0, and 3.8mm±2.7 respectively in PS TKAs. There was a significant difference between group 2 and 4 ($p<0.05$). The results in this study have demonstrated that obtaining images at least every 10 degrees should result in more accurate analysis of in vivo kinematics of deep bending motion after TKA.

A5-3

IN-VIVO QUANTIFICATION OF THE EFFECT OF SLIP AND FRICTION AT THE KNEE JOINT

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Mathematical modeling provides a cost effective, parametric alternative to telemetry in the determination of in-vivo joint forces. However, due to the complexity of the human body, modeling requires simplifying assumptions to generate a solution. Therefore a comparison between the data generated by a model to those obtained experimentally using telemetry becomes very important in order to validate the derived results. Various types of knee models have been published in the past. These include 2D models, treating the knee as hinged joint, 3D models treating the knee as a ball and socket joint and the more advanced models treating the knee as a 6 degree of freedom (DOF) joint. Also, since joints in the body have very low coefficients of friction, it has been mostly neglected in previous analyses.. The objective of this study was to quantify and understand the effect friction and slip and whether neglecting them is justifiable. The study compares data experimentally measured from a telemetric knee implant to the data obtained from two 3D inverse dynamic mathematical models of the knee– one neglecting the effect of slip and friction (Model 1) and the other incorporating them (Model 2).

The telemetric patient was analyzed under fluoroscopic surveillance while performing a deep knee bend activity. In-vivo translational and rotational kinematic values, obtained using a 3D to 2D image registration technique, were input in two different 3D inverse dynamic mathematical models. Both the mathematical models represent the bones as rigid bodies, musculotendonous units as linear elements and ligaments as non-linear elastic element. However, while the Model 1 treated the knee as a 3DOF ball and socket joint having a variable location to account for the variation in the contact points, Model 2 treated the knee as a 6DOF joint and incorporated friction and slip into the analysis. A constant frictional co-efficient of 0.05 was used.

For the entire flexion cycle, Model 2 predicted values closer to the actual telemetered value compared to Model 1. The maximum telemetric force was around 3.84BW at 103º while the first mathematical model predicted a value of 3.77BW at 91º and the second model predicted a value of 3.81BW at 100º of flexion. The greatest difference in the values obtained from telemetry and that obtained from the models occurred at full extension. This might be due to isometric contraction of the quadriceps, which the models failed to replicate since the subject is in a static position at full extension. Interestingly, the medial and lateral condylar forces were found to be similar in magnitude for the telemetric implant and the model. This might be the effect of ligament balancing during surgery since surgeons attempt to create a rectangular gap.

This study demonstrates that modeling the knee with 6DOF of freedom with friction and slip does provide with a greater accuracy in the prediction of the contact forces. However, this accuracy is obtained at the expense of computational speed.

A5-4

TOTAL KNEE ARTHROPLASTY FOLLOWING HIGH TIBIAL OSTEOTOMY

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INTRODUCTION

High tibial osteotomy is an efficient treatment for medial compartment osteoarthritis of the knee; its used for middle aged patients with high activity levels and can delay the need for total arthroplasty.

The results of total knee arthroplasty after failed high tibial osteotomy are controversies; several authors reported inferior outcomes, but others have concluded that tibial osteotomy doesn't bias following total arthroplasty. The aim of this study was to evaluate the results of failed high tibial osteotomy subsequently converted to total knee arthroplasty and compare the results to group of patients underwere primary arthroplasty; the authors evaluate some of technical problems that a previous high tibial osteotomy can generate, like scar tissue, patellar tendon shortening and changes of proximal tibial anatomy.

METHODS

50 total knee arthroplasty performed after a previous closed wedge osteotomy were matched with 50 patients operated with a primary knee prosthesis for osteoarthritis. The time from a proximal tibial osteotomy to a prosthesis operation was in mean eight years.

RESULTS

The Knee Society clinical and radiographic score system and W.O.M.A.C. evaluation were used to evaluate knees before surgery and at each follow up (average 5 years).

At an average of five years follow up, the clinical results of total knee arthroplasty after high tibial osteotomy were similar to those of primary knee prosthesis.

CONCLUSION

In our study revision of failed proximal tibial osteotomy appears to have more technical difficulties but with overall outcomes that remain comparable at results after primary total knee arthroplasty, so tibial osteotomy is considered a valid option in younger and very active patients with unicompartmental arthritis.

A5-5

THIGH-CALF CONTACT FORCES IN DEEP KNEE FLEXION

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INTRODUCTION

Recently, high-flexion knee prostheses were introduced to improve the range of motion of knee patients. Knee joint forces increase when higher flexion angles take place and put higher demands on knee prostheses. Joint forces are often estimated by simplified musculo-skeletal models using inverse dynamics. However, these models do not include thigh-calf contact which occurs in deep knee flexion. Thigh-calf contact is expected to reduce muscle forces in the knee and should in that case not be neglected.

In this study we measured thigh-calf contact forces and determined the magnitude and location of the resultant force on the calf. Two deep knee flexion activities were selected: squatting and kneeling.

MATERIALS AND METHODS

Ten healthy test persons with an average weight of 71.5±15.7 kg and an average length of 181±9.2 cm were included in the experiment. The contact forces between the thigh and calf were measured with a pressure mapping sensor (Tekscan Conformat). The sensing area of this sensor was 47x47 cm and the sensor contained 1024 pressure sensors. Before application the mapping sensor was calibrated carefully and inserted between the thigh and calf of both legs. Contact forces were normalized for body weights and both legs were averaged to represent one leg. Simultaneously, knee flexion angles were measured unilaterally with an infrared motion capture system (Qualisys).

RESULTS

In general, thigh-calf contact below 130 degrees knee flexion did not take place during deep knee flexion activities. Considerable thigh-calf contact (> 5% BW for one leg) occurred at an average knee flexion angle of 134.8±5.92(SD) degrees during squatting and 144.8±3.52 degrees knee flexion during kneeling. Maximal contact forces were measured when the knees were maximally flexed. Average maximal contact forces of 34.2±9.69% BW and 30.9±9.31% BW per leg were measured for squatting and kneeling, respectively. Standard deviations were relatively high indicating high variability amongst the subjects. The corresponding average flexion angles were 151.8±4.39 degrees for squatting and 156.4±3.67 degrees for kneeling. At these maxima, the average location of the resultant contact force on the calf with respect to the epicondyles was 15.1±2.38 cm for squatting and 16.6±2.64 for kneeling.

DISCUSSION

The measurements indicate that both the angle at which thigh-calf contact initiates and the maximum flexion angle and force differ from one person to another. Variations in leg dimensions and knee mobility play a role in these findings. As opposed to what is common in high-flexion knee force calculations the thigh-calf contact is too prominent to neglect (> 30% BW on one leg). Thigh-calf contact is likely to have a considerable effect on the forces inside the knee during deep knee flexion and should be included in studies that analyse knee biomechanics and prosthetic behaviour under these circumstances. With the data presented in this study more realistic high-flexion knee simulations can be obtained.

A5-6

SURFACE GUIDED TOTAL KNEE DESIGN FOR NORMAL KINEMATICS

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INTRODUCTION

Studies on knee specimens and the living knee have shown that the neutral path of motion consists of progressive posterior displacement of the lateral femoral condyle with flexion, and a constant position of the medial condyle, except for a few millimeters of displacement and even distraction in high flexion. This motion has been described as a synchronous flexion of the femur about an epicondylar axis and an internal tibial rotation about a medial axis in the tibia. (Iwaki et al, 2000; Dennis et al, 2001; Hollister et al, 1993; Churchill et al, 1998; Li et al, 2003). However such motion has usually not been reproduced after total knee (TKR), as evidenced by anterior femoral displacement in early flexion (paradoxical motion), a variable pivot point, and reduced posterior displacement and internal rotation (Dennis et al, 2003; Most et al, 2005). The purpose of our study was to design TKR models with various surface features which were intended to reproduce the normal neutral path of motion, and to compare the motion of such knee models with standard reference designs.

RESULTS

With axial loading, for the total condylar model, the femur stayed close to the bottom of the dish throughout flexion with no posterior displacement or rotation. For the standard PS, the same behaviour occurred, but after 90 deg flexion there was posterior displacement. The basic ramp model showed displacement after 60 deg flexion. The medial pivot model showed progressive external femoral rotation after 60 deg flexion with a stable medial side.

When an anterior shear force was superimposed, there was anterior femoral displacement throughout flexion for the total condylar model, and up to 90 deg flexion for the PS model, representing paradoxical motion. However, the ramp model with the anterior condylar feature, showed no anterior femoral displacement at all.

DISCUSSION

These experiments showed that existing total condylar and PS types of TKR do not have a mechanism for producing rotation in flexion and are susceptible to paradoxical motion. Ramp designs can produce earlier femoral rollback, have an improved patella groove, and a reduced intercondylar cutout. The combination of the ramp and an anterior condylar feature, produced motion similar to that of the normal knee, even when an anterior shear force was applied. Further research under additional loading conditions will investigate whether such features can be applied to a design for clinical use.

A5-7
APPLICATION OF KNEE MECHANICS

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It has been said that perfect is the enemy of good.

Replacement arthroplasty of the human hip and knee is one of the great medical achievements of the 20th Century. The question, however, remains-- is the continued pursuit of technological perfection advisable? This talk will examine this question in the short, intermediate, and long-term, concluding with a ten-word prediction of the future of joint replacement arthroplasty in the 21st Century.

A6-1

MATERNAL AND UMBILICAL CORD BLOOD LEVELS OF COBALT AND CHROMIUM IN WOMEN WITH METAL-METAL RESURFACINGS

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A. INTRODUCTION

The usage of metal-metal bearings in young patients has revived the concern of the potential adverse effects of elevated metal ions on offspring born to them. This study aims to answer the question if metal ions are transferred to the developing fetus.

B. MATERIAL & METHODS

After informed consent, whole blood specimens were obtained at the time of delivery from ten patients who had undergone a Birmingham Hip Resurfacing and from their babies' umbilical cords. High resolution plasma mass spectrometry (HRICPMS) was used for analysis.

C. RESULTS

Cobalt and chromium ions were detected in all the specimens obtained. The cord blood cobalt levels were lower than the mothers blood levels in all the specimens. A similar relationship was found in all but one individual chromium measurement. The mean cobalt levels in the mother's blood and cord blood were 1.39 µg/l and 0.84µg/l and those of chromium were 1.29 and 0.38 µg/l respectively. Using the 95% confidence intervals, the difference was sufficient to be statistically significant for chromium but not for cobalt.

D. DISCUSSION & CONCLUSIONS

The present study shows that with the use of whole blood specimens and HRICPMS cobalt and chromium ions can be detected in all specimens of patients with metal-metal devices and in the cord blood of babies born to them. This shows that metal ions cross the placenta. There is therefore a continuing need for vigilance on the possible effects on the offspring born to patients with metal-metal devices.

A6-2

ENVIRONMENTAL PHASE STABILITY AND RESIDUAL STRESS FIELDS IN ZIRCONIA ALUMINA MATRIX COMPOSITE

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Zirconia and alumina matrix composite (AMC) has been widely used for artificial hip and knee joints because of its stability in human body and superior wear resistance. The excellent mechanical properties of strength and fracture toughness of zirconia materials are well-known to be closely related to stress-induced transformation from the tetragonal to the monoclinic phase, which is accompanied with 4% volume increase of the zirconia crystal cell. But, it is also to be considered that the material is prone to low temperature degradation under hydrothermal environment, like in the human body. This low temperature degradation is influenced by the tetragonal to the monoclinic phase transformation. Tetragonal to monoclinic transformation induces the formation of microcracks at the material surface, and an increase in surface. Microcracking leads to a decrease of mechanical properties, and this could explain the failure of implants after some year years in vivo. Therefore, it is very important to study how to prevent phase transformation in zirconia components. Transformed monoclinic zirconia percentage can be experimentally measured by Raman spectroscopy and the residual stress distribution, which is related to phase transformation, can be determined by a non-destructive piezo-spectroscopic analysis. In this paper, we noticed the relationship between grain size and phase stability, and attempted to evaluate it from both stress and mechanical properties points of view by Raman and fluorescence spectroscopy. As a result, when yttria-stabilized tetragonal zirconia polycrystals (3Y-TZP) has large grain size, high fracture toughness is achieved but the material is more prone to hydrothermally induced transformation. Transformation makes a large effect on fracture toughness and surface hardness, which were measured by Crack Opening Displacement (COD) method. It is possible to control phase transformation by choosing a material with fine grain size, however, the material may also lose its high fracture toughness. In AMC, transformation was also observed under the hydrothermal environment. Its progression rate was the same as 3Y-TZP with 0.3 □m grain size, but it developed because zirconia particles in AMC had about 0.5 □m grain size. The fracture toughness decreased with progressing phase transformation, and showed the same tendency as 3Y-TZP materials. This study shows the need for designing zirconia-based biomaterials with considering mechanical properties as well as phase stability.

A6-3

"THE SQUEAKING HIP:" AN UNDER-REPORTED PHENOMENON OF CERAMIC-ON-CERAMIC TOTAL HIP ARTHROPLASTY.

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BACKGROUND

The first ceramic-on-ceramic total hip arthroplasty in the U.S. became available for widespread use in March 2003. Early reports have demonstrated excellent clinical and radiographic results without catastrophic failure such as implant fracture associated with earlier designs. One report, however, has noted the presence of squeaks (1%) with vigorous activity during follow-up.

METHODS

Between March 2003 and May 2005, three surgeons performed 783 total hip replacements, of which 159 (143 patients) utilized a ceramic-on-ceramic bearing. These patients were followed prospectively using the modified Hospital for Special Surgery Hip score and a patient administered questionnaire. Additionally, a control group of 60 hips (48 patients) with a metal-on-poly bearing was matched to the ceramic group using age, gender and BMI to compare the incidence of squeaks and noises.

Radiographic evaluations of were made according to previously established criteria.

RESULTS

Approximately 20% (29/143) of patients in the ceramic group report their hip makes some type of noise after an average follow-up of one year. One third of these or 7% (10/143) describe the noise as an audible squeak during normal activities. Squeaking was reproduced during a simulated stair climb. Average HSS scores improved from 19.8 to 38.4 indicating excellent clinical results. 90% of patients had satisfaction rates greater than 8 out of 10. There were 3 dislocations (1.9%), one of which squeaked and was revised for recurrent dislocation. There were no other re-operations. One patient is considering revision to eliminate his squeak. There were no cases of deep sepsis.

In the matched metal-on-poly cohort, the incidence of some type of noise was 4% (2/48). There were no squeaks in this group.

There were no cases of radiographic loosening or malalignment.

CONCLUSION

The squeaking hip is a peculiar phenomenon unique to hard-on-hard total hips. The squeak does not appear to be the result of impingement or impending failure. The causes and implications of squeaking are yet to be determined. Nonetheless, patients considering ceramic-on-ceramic bearings should be counseled accordingly.

A6-4

THE DIFFERENT EFFECTS OF SERUM AND WHOLE BLOOD ON FRICTION IN METAL-METAL BEARINGS OF DIFFERENT CLEARANCES

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A. INTRODUCTION

Modern cementless joints depend on bony ingrowth for durable long term fixation. Increased friction and micromotion in the early weeks can prevent ingrowth and affect long-term success. Most friction studies are conducted in a bovine serum- carboxymethylcellulose (BS-CMC) medium. Following implantation however, the joint is bathed in blood which contains macromolecules and cells. The effect of these on friction is not fully understood. The purpose of this investigation was to study the effect of using whole blood as a lubricant on friction for a given bearing diameter and deifferent clearances.

B. MATERIAL & METHODS

Frictional measurements were carried out on a Prosim Hip Friction Simulator (Simsol Simulation Solutions, Stockport, UK). Six Birmingham Hip Resurfacing devices with a nominal diameter of 50mm each and a range of diametral clearances (80, 135, 175, 200, 243 and 306μm) were used. The test was conducted sequentially with whole blood (viscosity 0.009Pas) and a BS-CMC mixture as the lubricants (viscosity 0.01Pas).

C. RESULTS

Low clearance devices (80-175μm) generated higher friction with blood than with BS-CMC. With blood as the lubricant, low clearance devices (80-175μm) generated much higher friction than higher clearance devices (200-306μm).

D. DISCUSSION & CONCLUSIONS

Ongoing research into the in vitro performance of bearings is performed in hip simulators with lubricants that are believed to simulate joint fluid in terms of viscosity. However these lubricants are unable to simulate the friction effects of macromolecules.

The results of this study suggest that reduced clearance bearings have the potential to generate higher friction when blood is the lubricant. This higher friction in the low clearance bearings may produce micromotion in the early postoperative period and hamper bony ingrowth resulting in impaired fixation with long-term implications for survival.

A6-5

TWO TO EIGHT YEAR FOLLOW UP EXPERIENCE WITH CERAMIC CERAMIC TOTAL HIP ARTHROPLASTY

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Implant wear and wear-associated debris are common problems encountered after total hip arthroplasty. Subsequent complications include occurrence of osteolysis, decreased prosthesis survival and early failure, ultimately requiring revision of the prosthesis system. Important alterations to the widely used metal-on-polyethylene bearings have been made and other hard bearings like metal-on-metal bearings have been introduced. However the problem of wear, subsequent osteolysis and bioreactivity to wear particles is still existent in these bearings. Ceramic-Ceramic bearing surfaces are a promising alternative to these materials showing less wear and bioreactivity.

194 THA were performed on 173 patients using alumina ceramic-ceramic bearings. Patients were followed up and evaluated clinically and radiographically for a minimum of 2 years. Survival rate, implant- and non-implant related complications were investigated. Signs of osteolysis, component loosening and implant wear were assessed radiographically. Clinical outcome was examined and quantified using the Merle d' Aubigné Score.

No case of osteolysis occurred after more than 8 years follow up time. The survival rate for all patients without previous surgery was 99.4% (CI 89-100). The incidence of prosthesis related complications was very low compared to the literature (2%). Overall complication rate was excellent. The Merle d'Aubigné score at long term had a mean of 17.56 of 18 points and there was a significant improvement compared to the preoperative results.

This study underlines and reassures the outstanding properties of alumina ceramic-ceramic hip implants regarding prosthesis survival, wear characteristics and clinical long term results. It also demonstrates the superiority of these implants compared to other combinations of bearing materials like metal on polyethylene or metal on metal prosthesis systems.

Total Hip Arthroplasty using alumina ceramic-ceramic implants is a safe and reliable procedure in the comparably young and active patient.

HAP Paul Award

A7-1

TOCOPHEROL STABILIZATION OF IRRADIATED UHMWPE: A SECOND GENERATION HIGHLY CROSS-LINKED UHMWPE WITH IMPROVED FATIGUE RESISTANCE FOR TOTAL KNEES

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One major concern limiting the use of wear-resistant highly cross-linked and melted ultra-high molecular weight (UHMWPE) in total knee arthroplasty is the decrease in fatigue strength. In the past five years our research has been focused on improving the mechanical strength and fatigue resistance of highly crosslinked UHMWPE. We discovered that eliminating post-irradiation melting and stabilizing the residual free radicals of radiation crosslinked UHMWPE with α-tocopherol (Vitamin-E) resulted in improved mechanical properties and fatigue crack propagation resistance without compromising the wear resistance of the polymer. We designed a cantilever post bending test to determine the fatigue crack initiation resistance of vitamin E-doped, irradiated UHMWPE (α-TPE) in comparison to cross-linked and melted and conventional UHMWPEs. The bending fatigue behavior of α-TPE was comparable to conventional UHMWPE. Upon accelerated aging the bending fatigue resistance of conventional UHMWPE decreased substantially while that of α-TPE showed no detectable changes. Our previous investigations with α-TPE showed improved wear and oxidation resistance, migration stability of α-tocopherol, and improved mechanical properties; therefore, we advance the use of this material in total knee arthroplasty where high stresses may not allow the use of the first generation highly crosslinked UHMWPEs.

Keywords: Total knee arthroplasty, highly cross-linked polyethylene, oxidation resistance, fatigue resistance, vitamin E, biomaterials

A7-2

MAGNETIC RESONANCE IMAGING IN THE DIAGNOSIS AND MANAGEMENT OF WEAR-INDUCED PERI-PROSTHETIC INFLAMMATION AND OSTEOLYSIS FOLLOWING TOTAL HIP ARTHROPLASTY

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The evaluation of hip pain following total hip arthroplasty is often challenging in the absence of obvious radiographic pathology. Recent advances in magnetic resonance imaging sequencing have greatly improved its diagnostic utility by decreasing metallic artifact. The purpose of this study was to investigate the use of a modified, commercially available magnetic resonance technique in the diagnosis and management of wear-induced peri-prosthetic inflammation and osteolysis in patients presenting with pain after total hip arthroplasty.

Eighteen patients (twenty hips) were evaluated with magnetic resonance imaging after presenting with pain following total hip arthroplasty. Most patients had little or no wear, without definitive evidence of loosening or osteolysis; three did show osteolysis but had symptoms which did not fit with or were out of proportion to the radiographic findings. All patients were screened for deep sepsis using where appropriate using sedimentation rate and C-reactive protein. The magnetic resonance images were examined for the presence of peri-prosthetic pathology at the bone-implant interface and surrounding soft tissue, and these findings were used to initiate a treatment algorithm consisting of activity modification, non-steroidal anti-inflammatories, bisphosphonates, fluid aspiration, steroid injections, or revision surgery.

Pathology was found in all twenty hips, including abductor tendinosis (sixteen), femoral osteolysis (eight), peri-acetabular osteolysis (seven), iliopsoas bursitis (six), particle-induced synovitis (six), iliopsoas tendinosis (five), soft-tissue ganglia (three), scarring of the pseudocapsule (three), trochanteric bursitis (two), and thickening of the iliopsoas bursa (one). Using these results, thirteen patients were successfully treated with conservative management (seven with activity modification, four with non-steroidal anti-inflammatories, and four with bisphosphonates), one had a therapeutic aspiration, and four underwent revision surgery. In addition, these findings likely prevented at least four unnecessary revisions which were being strongly considered prior to obtaining the magnetic resonance studies.

Recent advances in magnetic resonance sequencing have improved its effectiveness in visualizing a wide range of disorders at the bone-implant interface and surrounding soft tissues following total hip arthroplasty. As a result, the diagnostic accuracy of magnetic resonance imaging can be used successfully in a treatment algorithm to determine the most appropriate intervention for these disorders.

A7-3

THE WEAR PERFORMANCE OF A FLEXIBLE, ANATOMICALLY LOADED CFR-PEEK HIP CUP DESIGN

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'New' material combinations have been introduced as the bearing surfaces of prostheses to try and overcome the problem of osteolysis often attributed to polyethylene wear particles liberated within conventional metal-on-ultra-high molecular weight polyethylene (UHMWPE) joints. This study uses a hip simulator to assess the volumetric wear rates of carbon fibre reinforced polyetheretherketone (CFR-PEEK) acetabular cups articulating against alumina femoral heads.

MATERIALS AND METHODS

The wear test was performed on the Durham hip joint wear simulator. Six 54 mm diameter, alumina-on-CFR-PEEK joints were supplied by Stryker Orthopaedics. These were anatomically loaded within the simulator. Five joints were wear tested and the remaining joint was used as a loaded soak control. Every 500,000 cycles, the wear of the acetabular cups was assessed gravimetrically (using a Mettler Toledo AX 205 balance, accurate to 0.01 mg) and the loaded soak control was used to take account of any change in weight due to lubricant absorption. The joints were tested to 25 million cycles (equivalent to approximately 25 years in vivo) with 30% new-born calf serum as the lubricant. Throughout the wear test the surface topography was measured on the Zygo NewView 100 non-contacting profilometer.

RESULTS AND DISCUSSION:

These joints provided encouragingly low wear results. The average volumetric wear rate of the five joints tested in this study was 1.162 mm^3/million cycles (range 0.811 to 1.320 mm^3/million cycles). This is significantly lower than the wear rate of ceramic-on-UHMWPE joints (38.6 mm^3/million cycles) [1] and similar to metal-on-metal resurfacing prostheses which have shown slightly lower wear rates to those found in this study (0.67 mm^3/million cycles for the cup and head wear combined [2]). The surface topographical analysis of the CFR-PEEK acetabular cups showed a reduction in surface roughness and also a change to more negative skewness (i.e. more valleys than peaks) which may aid in lubrication.

CONCLUSIONS:

The low wear produced by these alumina-on-CFR PEEK hip joints is considerably lower than conventional metal-on-UHMWPE joints and is of the same order of magnitude as the wear produced by metal-on-metal joints. These results show that this novel joint couple may potentially be an alternative solution for the reduction of osteolysis. The authors wish to thank Stryker Orthopaedics for funding this research.

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A7-4

WEAR OF POLYETHYLENE AGAINST METAL-CERAMIC COMPOSITE FEMORAL COMPONENT: EFFECT OF AGGRESSIVE KINEMATIC CONDITIONS

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Zirconium is a metal with excellent biocompatibility, which when oxidized is converted to the ceramic, zirconia. Composite-bearing materials have recently become available consisting of a metal zirconium core with an oxidized zirconia surface. The metal-ceramic composite has the wear characteristics of a ceramic bearing but with a much lower propensity for fracture. This dual advantage makes it an attractive alternative as a bearing surface for total knee arthroplasty (TKA). This study was designed to determine if the advantages of low wear were also seen under aggressive kinematics and loading conditions.

Three oxidized zirconium femoral components (OxZirc) and three femoral components of identical geometry made of conventional cobalt-chrome-molybdenum alloy (CoCr) were mounted in a six-station knee wear simulator (AMTI, Watertown, MA) and were tested against six tibial noncrosslinked polyethylene inserts (sterilized by ethylene oxide) in modular tibial base-plates. Lubricant used was 90% bovine serum supplemented with EDTA and sodium azide. The components were subjected to five million gait cycles per ISO recommendations with the following modifications: mediolateral distribution of the vertical tibial load was increased to 75:25 (ISO recommended 60:40) to represent the distribution of load due to the mechanical axis of the knee passing more medially through the joint line; the magnitude of tibial axial rotation was increased to 20°. These conditions were chosen to simulate an athletically active patient with less than optimal knee alignment. Gravimetric wear was measured by weighing the polyethylene inserts at 500,000 cycle intervals. Soaked controls were used to correct for weight gain due to fluid absorption. Volumetric wear was measured by surface mapping the inserts using a laser displacement sensor. Volumetric loss was converted to weight loss by multiplying with the nominal density of UHMWPE. Volumetric wear measurements were calculated between the 2.5 million and the 5 million cycle time points since polyethylene inserts creep very little after 2.5 million cycles. Compared to our previous study (Ezzet et al, Clin Orthop, 2004), increased tibial rotation together with increased medial loading almost doubled the wear in the cobalt-chrome groups (from 20 to 39 mg/million cycles). The wear rate also increased in the oxidized zirconium group, although by a smaller percentage (from 12 to17 mg/million cycles). The oxidized zirconium group therefore maintained their advantage of lower wear even under aggressive testing conditions (approximately 55% reduction in wear).

Alternative bearing surfaces such as ceramic-on-ceramic, metal-on-metal, and highly crosslinked polyethylenes have been shown to be successful in reducing wear rates in hip arthroplasty. In the knee, these bearings may have an unacceptably high failure rate. Ceramic-on-ceramic bearings can fracture under impact or edge loading. Metal-on-metal surfaces perform best within a narrow threshold of tolerance between mating articular surfaces and would be highly sensitive to the relatively lower conformity in knee design. Finally, there is an increased potential for damage and fatigue failure in highly crosslinked polyethylene. "Metal-ceramic composites" may emerge as promising alternative bearing surfaces for TKA prostheses.

A7-5

LARGE DIAMETER FEMORAL HEADS ON HIGHLY CROSS-LINKED POLYETHYLENE: MINIMUM THREE YEAR RESULTS

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Contemporary highly cross-linked polyethylenes have become the most widely used alternative bearing surfaces in THR and may be paired with large diameter femoral heads (> 32 mm) in patients that are considered to be at high risk for dislocation. We report on a prospective series of 42 patients (45 hips) who had THR using large diameter cobalt-chrome femoral heads articulating with a highly cross linked polyethylene after a minimum of 3 years follow-up (mean 3.3 years). At final follow-up, the final patient cohort showed excellent clinical results with no radiographic failures or episodes of loosening. There was no evidence of pelvic or femoral osteolysis. One patient sustained a dislocation due to a grossly malpositioned acetabular component necessitating early isolated acetabular revision. The average yearly steady state wear rate was -0.06 ± 0.41mm/year. The results of our short-term prospective series indicated that THR with large femoral heads articulating with a highly cross linked polyethylene showed excellent wear characteristics and clinical results and could be considered in patients at increased risk for dislocation.

A7-6

DIFFERENCES IN HIGHLY CROSS-LINKED POLYETHYLENE WEAR BETWEEN SECOND GENERATION ZIRCONIA AND COBALT CHROME FEMORAL HEADS

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INTRODUCTION

The zirconia femoral head was introduced as an alternative to those made from alumina ceramic. Femoral heads made from zirconium ceramic are considered less likely to fracture and to have a lower wear rate against UHMWPE than femoral heads made from stainless steel or cobalt chrome. However, several reports on total hip arthroplasty with a zirconia femoral head have noted poor wear characteristics. One cause is thought to be the phase transformation of zirconia in vivo. The present study reviewed the results of the wear performance of second generation zirconia (3Y-TZP, JAPAN MEDICAL MATERIAL) and cobalt-chromium femoral heads articulating against a highly crosslinked polyethylene liner (EONIAN, JAPAN MEDICAL MATERIAL).

METHODS

Between 2000 and 2002, 60 patients had a primary cementless total hip arthroplasty with the zirconia femoral head or cobalt chrome femoral head. Gender distribution, average age at surgery, average weight and average follow-up period were same in the two groups. The average follow-up period was 4 years (range, 3 to 5 years). The average age at the time of surgery was 61 years.

Porous acetabular shells and highly crosslinked polyethylene liners made by Japan Medical Material were implanted into all hips. The mean diameter of the shell implanted in the zirconia head group was 47 mm and in the metal group it was 48 mm. The zirconia and the cobalt chrome femoral heads used were both 26-mm. The zirconia was tetragonal zirconium oxide polycrystal containing 3 mol% yttria oxide for stabilization treated with hot isostatic pressure. Custom-made or PerFix femoral components made of titanium alloy (JAPAN MEDICAL MATERIAL) were implanted with a standardized posterolateral surgical approach without trochanteric osteotomy. Post-op radiographs of these patients were evaluated using the Vector works software and modified Kabo equation.

RESULTS

The mean amount of polyethylene linear wear was 0.05 mm/yr in the zirconia head group and 0.06 mm/yr in the cobalt-chromium head group. The mean amount of volumetric polyethylene wear was 14.7 mm^3 in the zirconia head group and 15.5 mm^3 in the cobalt-chromium head group. Differences were not significant in the two groups. Mean annual wear was almost same in both groups with most wear being observed to occur in the first year. After the bedding-in phase, the mean annual wear was just 0.01 mm in both groups.

DISCUSSION

Zirconia ceramic has three phases of crystalline structure that vary with temperature. Such phase transformation can be accompanied by up to a 3% change in the volume of the ceramic head and may cause an increase in surface roughness. However, Kim et al. recently reported a better wear performance for zirconia femoral heads than for cobalt chromium ones. The present results suggest that cross-linked polyethylenes combination with two types of femoral heads hold great hopes for reduction in wear performance. There was no significant difference between second generation zirconia femoral head and cobalt-chromium femoral head. Longer follow-up is required to evaluate if this new material is associated with less occurrence of osteolysis.

A7-7

COMPARISON OF ACETABULAR POLYETHYLENE WEAR RATES BETWEEN HIGHLY CROSSLINKED AND TRADITIONAL POLYETHYLENES – A MINIMUM FIVE YEAR FOLLOW-UP STUDY

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INTRODUCTION

Highly cross-linked polyethylene can reduce linear wear by 50-90% when compared to traditional polyethylene (gamma sterilized in air) in wear simulator studies. The polyethelene under study is irradiated to 10 Mrads to achieve cross linking, and cold annealed, but not remelted. The purpose of this study was to compare the linear wear rates of a highly cross-linked polyethylene to traditional polyethylene.

METHODS

Twenty-five highly cross-linked polyethylene components (in 22 patients) and 25 traditional (3 Mrads in inert gas) components (in 22 patients) were included in the study. The two groups were matched with respect to age, gender, height, weight, and activity level. All surgeries were performed by a single surgeon using the same implant designs. Linear wear was measured utilizing Martell's computerized technique.

RESULTS

The highly cross-linked group and the traditional group were followed for a mean of 71 months (range, 60 to 87) and 75 months (range, 60 to 97) respectively. The mean penetration rate for the highly cross-linked and traditional polyethylene was 0.045mm/yr (SD=0.044) and 0.120 mm/yr (SD=0.070) respectively. The mean total penetration for the highly cross-linked group was 0.283 millimeters (SD= 0.253) and 0.696 millimeters (SD=0.402) for the traditional group. The difference in linear wear was highly significant at $p=<0.001$.

CONCLUSION

Cross-linking has been shown to improve wear performance of polyethylene. Our experience demonstrates a 63 percent reduction in wear over traditional polyethylene at a minimum of five years. Highly cross-linked polyethylene significantly reduces wear and may minimize future osteolysis thus increasing the longevity of total hip arthroplasty.

A7-8

SURFACE AND BULK PROPERTIES OF 2-METHACRYLOYLOXYETHYL PHOSPHORYLCHOLINE GRAFTED CROSS-LINKED POLYETHYLENE

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INTRODUCTION

Osteolysis caused by wear particles from polyethylene in the artificial hip joints is a serious issue. We have used photo-induced radical polymerization to graft 2-methacryloyloxyethyl phosphorylcholine (MPC) polymer onto the surface of cross-linked polyethylene (CLPE-*g*-MPC) in order to reduce friction and wear at the bearing surface of the joint. In this study, we investigated the effects of this photo-induced radical graft polymerization technique on surface and bulk properties of CLPE-*g*-MPC.

METHODS

Surface chemical properties of the CLPE and CLPE-*g*-MPC were examined by Fourier-transform infrared spectroscopy and X-ray photoelectron spectroscopy. Surface wettability of the CLPE and CLPE-*g*-MPC were examined by the spray method is based on the wetting response of the surface of a cup when exposured to a water mist. The density, swelling ratio, network chain density, molecular weight between cross-links and cross-link density, of CLPE and CLPE-*g*-MPC were evaluated. The mechanical properties of CLPE and CLPE-*g*-MPC were evaluated with tensile, impact, and creep deformation tests, as well as a shore hardness D measurement. The *in vitro* wear test was performed using an MTS hip joint simulator. The acetabular component (26 mm inner diameter and 52 mm outer diameter) was tested with a Co-Cr-Mo alloy femoral head. Testing then continued until a total of 3.0 x 10^6 cycles were completed.

RESULTS

The physical and mechanical properties of CLPE and CLPE-*g*-MPC were not significantly different, expect that the friction coefficient of untreated CLPE cups was 0.0075, compared with 0.0009 for CLPE-*g*-MPC cup, an 88% reduction. After 3.0 x 10^6 cycles in the hip joint simulator test, we could not confirm any wear of MPC-*g*-CLPE cups.

DISCUSSION

After the hip joint simulator test, we confirmed that the CLPE-*g*-MPC cups showed a quite low wear rate compared with untreated CLPE. Since MPC is a highly hydrophilic compound, the water-wettability of the CLPE-*g*-MPC surface was greater than that of a CLPE surface due to the poly(MPC) chains. It was observed that the CLPE-*g*-MPC surface supported a thin film of water. The artificial hip joint bearing with an CLPE-*g*-MPC surface had high lubricity. This high lubricity is assumed to have contributed to the improvement of anti-wear properties that was observed. The physical and mechanical properties of the CLPE substrate were unchanged even after the addition of a layer of MPC polymer by photo-polymerization. We concluded that the advantage of this photo-induced radical graft polymerization technique was that the grafted MPC polymer layer produces high lubricity while only affecting the surface, and has no effect on the bulk properties of the CLPE substrate.

A8-1

TOTAL HIP ARTHROPLASTY PERFORMED USING CONVENTIONAL AND COMPUTER-ASSISTED AND TISSUE-PRESERVING TECHNIQUES

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Less invasive techniques in THA have been associated with higher peri- and postoperative complication. With the goal of addressing these issues, a technique of tissue-preserving, computer-assisted THA was developed, preserving the soft tissue surrounding the hip joint and protecting the abductor musculature. The technique involves inserting both the femoral and acetabular components anterior to the posterior capsule and short rotators and posterior to the gluteus medius and minimus. The technique was designed to easily incorporate surgical navigation into the procedure.

115 consecutive computer-assisted THA performed using a tissue-preserving technique through a superior capsulotomy (study group) were compared to 128 consecutive THA performed using a modified transgluteal exposure without computer-assistance (control group). Both groups were studied prospectively using the same standardized hip function questionnaires, the same examination parameters, and the same radiographic views. Evaluations were performed pre-operatively and at the first (up to 9 weeks) and second visits (up to 24 weeks) post-operatively. A Merle d' Aubigne score was calculated at each visit.

The study group had a significant improvement in the Merle d'Aubigné hip score at the 1st and 2nd follow up visit although having had a significantly worse score preoperatively. Furthermore patients in this group had a lower complication rate (2.6%) compared to the control group (4.7%). The mean cup abduction angle was 43.6° for the study group and 41.6° for the control group. The difference was statistically different ($p < 0.0001$). Further, the standard deviation in cup abduction was 3.6 for the study group and 4.7 for the control group. The smaller standard deviation in the study group was also statistically different ($p = 0.009$).

The patients treated by the superior capsulotomy technique experienced a faster recovery than the control group and this difference was remained at 3 months following surgery. The study demonstrates that, contrary to prior reports on "minimally invasive" hip surgery, cup position was more reliable (significantly smaller standard deviation) through the small incision using computer-assistance than it was using a larger incision without computer-assistance. Furthermore it is clear that, contrary to previous studies, the complication rate and reoperation rate following total hip arthroplasty using a superior capsulotomy and computer-assistance was not higher than with conventional total hip arthroplasty.

A8-2

A STUDY OF SAGITTAL SACRAL TILT AS A MEASURE OF PELVIC INCLINATION AND ACETABULAR VERSION

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Several studies have reported the change in orientation of the acetabular component with various pelvic positions and its changes during activities of daily living such as lying, standing and sitting. We could not find any paper comparing CT evaluation with radiographs in different positions of sitting, standing and supine to study the direct influence of pelvic tilt on acetabular anteversion. The aim of this study was to determine the change of functional acetabular anteversion depending on the various positions of the pelvis in lying, standing and sitting position in a group of the patients after THA by comparing CT scans and radiographs.

This study included 40 patients after THA with mean age 53 years. Controlled lateral radiographs of the lumbo sacral spine and pelvis in the supine, standing and sitting positions were obtained. CT scans of the pelvis were also obtained in supine position after THA. The pelvic tilt was measured by the sagittal sacral tilt (ST) on the lateral radiograph in positions of sitting, standing and supine and on sagittal image of the CT scan. The acetabular orientation was measured by the Acetabular component tilt (AT) on the sagittal CT image and lateral radiograph of the pelvis. Anatomic anteversion was measured as the anterior tilt on the axial CT image.

The mean ST in lateral radiograph was 38.8°± 8.9° (range 17° to 56.1°) in the supine position, 34.9°± 9.5° (range 14° to 50°) in the standing position, and 17.5°± 17.4° (range -25°to 67°) in the sitting position and the mean sacral tilt in sagittal image of CT scan was 38.6°± 8.2° (range 20° to 54°). Tilt of acetabular components (AT) on the lateral radiograph was 20.5°± 13.1° (range -3.8° to 51°) in the supine position, 24.4°± 11.7° (range 2.6 °to 50°) in the standing position and 46.6° ±22.2°(range 15° to 92°) in sitting position . AT of acetabular components in CT scans was 19.5° ±9.9° (range 2.2° to 50°) in sagittal image. The anatomical anteversion was 19.3 ± 8.1, range (3 to 35.4) in axial image. There was no statistical difference between the measures of sacral inclination in supine radiograph and CT image ($p<0.05$). The acetabular tilt on radiographs in the different position was not significant statistically.

Our result showed that there was not only an intersubject variation in pelvic tilt on radiographs but also a significant variation of the functional acetabular anteversion related to the position of the pelvis during the activities of daily living. We conclude that the measurement of sagittal sacral tilt can be used as a reliable parameter to evaluate the pelvic tilt.

A8-3

A MORPHING BASED NAVIGATION SYSTEM FOR ARTHROSCOPIC FEMOROACETABULAR IMPINGEMENT SURGERY

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INTRODUCTION

Femoro-Acetabular Impingement (FAI) is believed to be a promoting factor for hip osteoarthritis, leading to Total Hip Arthroplasty. Early management of FAI could therefore significantly delay a THA.

Two types of impingement have been identified, in which either an abnormally shaped femoral head & neck (cam) or abnormal acetabular rim (pincer) impinge on the opposing normal joint side and limit the range of motion (ROM). Both lesions can also coexist in a patient with FAI.

Arthroscopic management of FAI is a viable alternative to open surgery. It is a technically demanding procedure however due to the reduced visualization, involved intra-operative setup, and need for supplementary imaging such as fluoroscopy which can be cumbersome. An intra-operative tool for identifying the location and degree of correction required to restore optimal joint function and ROM would therefore be of significant value.

MATERIALS AND METHODS

An image-free computer-assisted technique for FAI surgery is being developed at HSS. It requires attachment of a dynamic reference frame for tracking on both femur and pelvis bones. The anatomy of the lesion is first reconstructed using the PRAXIM BoneMorphing algorithms, where 3D statistical shape models are deformed to points acquired arthroscopically on the bone surfaces. The surgeon has the option whether to navigate only the femur or the pelvis for cam or pincer impingement respectively, or both bones when both sides are pathological.

The location of the zone of impingement can be identified either manually by the surgeon using the probe or automatically by the system when both surfaces are registered in impingement positions. An algorithm for predicting the volume of bone to be removed as a function of the desired improvement in ROM has been developed. Depending on whether only one or both sides of the joint are navigated, the system computes what milling depth from the bone surface corresponds to what increase in ROM, and displays this relationship on the screen during the milling process.

To augment visualization, the morphed model is virtually sculpted or remorphed on the screen in real-time while the surgeon removes bone using a tracked, calibrated burr of known geometry. Two algorithms for simulating this process were implemented and tested: a voxel-volume and a surface-remeshing approach. Various concepts for human machine interfaces to help guide the sculpting process have also been explored, including colour impingement maps and intensity/transparency distributions overlaid onto the bone models.

RESULTS AND DISCUSSION

The protocol has been integrated into a prototype application running on the PRAXIM navigation platform. Preliminary experiments on synthetic bones and a cadaver demonstrate satisfactory precision and good usability. Rendering using the voxel based approach provided a more realistic real-time visualization of the bone sculpting process (by successfully removing voxels that come into contact with the burr geometry) in comparison the slower more computationally intensive surface-remeshing algorithm. Real-time visualisation of the amount of bone removed appeared to be most effective using the colour map technique that identified successive target layers from the original surface as a colour spectrum to correlate the milling depth with ROM.

A8-4

IN VIVO COMPARISON OF HIP MECHANICS FOR SUBJECTS IMPLANTED WITH A MIS OR TRADITIONAL SURGICAL TECHNIQUE

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Sufficient exposure and visualization of anatomical landmarks are important factors during implantation of a total hip arthroplasty (THA). Previously, an incision length of up to 40 centimeters was expected, but more recently, minimally invasive surgery (MIS) procedures have been introduced, leading to smaller incisions. It is hypothesized that a MIS procedure may lead to less muscle damage and less rehabilitation time, but outcome studies determining differences between the procedures have yet to be conducted. Therefore, the objective of this study was to develop a mathematical model that determines the in vivo loading conditions of total hip arthroplasty (THA) and the soft-tissue associated with hip motion, implanted using either a MIS or traditional procedure.

A 3D mathematical model of the human lower extremity was developed using Kane's theory of Dynamics. Ten patients (5 MIS and 5 traditional) were asked to perform treadmill gait while under fluoroscopic surveillance. The average post-op time was only 4.2 months (range: 2 - 7 months) for the MIS subjects and 7.6 months (range: 3 - 12 months) for the traditional subjects. The fluoroscopic videos were digitized and frames were captured at toe-off, heal-strike, 33% of stance phase, 66% of stance phase, and at 4 separate instances during the swing phase and analyzed for their kinematics. Then, the in vivo kinematics were entered into the mathematical model to determine in vivo forces at the hip articulation and in the soft-tissues across the hip joint and comparisons were made during stance-phase and toe-off.

At heel-strike the average hip force was 1.68 and 1.84 times body weight (BW) for the MIS and traditional subjects, respectively. At mid-stance, where previous studies have demonstrated the occurrence of hip separation, the average force was 2.46 and 2.72 BW for the MIS and traditional subjects, respectively. At toe-off, a reversal of trends occurred, where the average force was 1.7 and 1.48 BW for the MIS and traditional subjects, respectively. There was no statistical difference in the data ($p>0.05$) for most of the gait cycle, but it must be noted that the MIS subjects were, on average, 3.4 months earlier post-operative. Further analysis for the maximum peak force revealed that the MIS subjects experienced a statistically lower value, based on a median test with a 90% confidence limit ($p=0.07$). Also, the force patterns for both groups followed similar paths, representing the patterns often seen the forces derived using telemetry. The MIS group did demonstrate a larger variance of the forces during the stance phase, which may be attributed to the early post-operative time for some of the subjects.

Subjects implanted using a MIS procedure experienced less hip force magnitudes than the traditional subjects at heel-strike and at mid-stance, but greater forces at toe-off. Clinically, these subjects also returned to normal force patterns quicker post-operatively, which may be a benefit. Further analysis of the data and more subjects need to be added to the study to determine if these trends will continue.

A8-5

THE ACCURACY OF DIGITAL TEMPLATING IN PRIMARY TOTAL HIP ARTHROPLASTY

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Successful hip reconstruction is predicated upon the proper restoration of normal hip biomechanics and selection of implants of appropriate size and geometry to avoid intraoperative and/or postoperative complications. This may aid to ensure long-lasting function and pain-relief. Digital preoperative planning enables the surgeon to select from a library of templates and electronically overlay them on a magnification-calibrated image, thus performing a 'dry-run' of the procedure prior to proceeding to the operative suite.

The purpose of this study was to assess the ability of digital templating to accurately predict implant size requirements at the time of primary total hip arthroplasty.

One hundred and thirty five consecutive primary total hip arthroplasties were templated preoperatively using the TraumaCad templating software (Orthocrat Ltd). Hips were templated using magnification-calibrated radiographs. For each hip, an AP pelvis, AP and false profile projection were used for the preoperative assessment. All acetabuli implanted were either Trilogy Trabecular Metal (Zimmer), Trident PSL (Stryker), or Pinnacle (DePuy) implants. Femoral stems were either Alloclassic or ML-Taper (Zimmer), Accolade or Exeter (Stryker), or Corail (DePuy). All hips were implanted by a single surgeon. Postoperatively, the predicted implant size was compared to the actual components selected at the time of surgery.

One hundred and thirty five hips in 135 patients were prospectively templated. The digital templating accurately predicted the exact size of the femoral component 71% of the time, was within 1 size 96% and within 2 sizes 100% of the time. Acetabuli were correctly predicted 74% of the time, within 1 size 97% and within 2 sizes 100% of the time. Intraoperative restoration of leg-lengths was highly reproducible and accurate, achieving a postoperative difference less than 5 mm in 89% of cases.

The surgeon’s ability to accurately predict the details of a planned joint reconstruction preoperatively enables him/her to perform a more predictable procedure, anticipating any technical challenges and helps to avoid many intra- and/or post-operative complications. To our knowledge, this is the largest series of digitally-templated hip arthroplasties reported. This technique proved highly accurate at predicting implant sizes and enabled proper restoration of leg-lengths. This accuracy transcended the multiple implant designs employed. The reliability demonstrated allows for improved efficiency during the procedure. It is likely that this technology (using magnification-calibrated images) enables more precise prediction of intraoperative needs when compared to the traditional film-based techniques (that relied upon estimations of magnification). In addition, this ability to preoperatively determine the needed size range (predicted, +/- 2 sizes above and below) enhances inventory control and patient safety.

A8-6

PREOERATIVE PLANNING SYSTEM OF TOTAL HIP ARTHROPLASTY

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INTRODUCTION

In Japan the common cause of osteoarthritis of the hip is acetabular dysplasia. Selection of the optimal socket and stem judging only by plain X-rays is not so easy, because deformity varies in each case and it is impossible to obtain a profile view of the hip. As osteoarthritic patients tend to develop external rotation contractures of the hip, radiographic positioning of the patients with the correct rotation is very difficult. For the solution of this problem, a 3-dimensional preoperative planning system of total hip arthroplasty was developed.

MATERIALS AND METHODS

Preoperative simulation was performed in 38 osteoarthritic hips in 35 patients (4 males and 31 females), and the mean age at the operation was 64 years old. The 3-dimensional geometry of the pelvis and the femur were reconstructed by the CAT scan DICOM data. The geometry of pelvis, femur, and components were placed on the same coordinate. Cross-sectional images from many directions were observed, and the optimal size of the cup and stem were selected. According to the result, actual operations were done. The planned size of the components and the selected size of the components at the operation were compared. As for the stem selection, we always start from Revelation (Encore, USA) cementless stem which has very high proximal fit-and-fill, insertability and applicability. If Revelation stem cannot restore the anteversion angle, we use modular stem.

RESULTS

Revelation stems were used in 34 hips, and modular stems were used in four hips with severe anteversion. Sockets preoperatively defined were used in 24 hips (63%) and 2mm large or small ones were used in 13 hips (34%). Stems preoperatively defined were used in 32 hips (94%) among Revelation cases.

Not only the size but also implant position, equalization of the leg length and impingement between osteophytes and the stem were possible to be evaluated preoperatively.

3-dimensional preoperative planning system has a good indication for cases with severely deformed hips.

A9-1

LEARNING CURVE IN LESS INVASIVE TOTAL HIP REPLACEMENT (THR)

Raj K. Sinha, MD, PhD

INTRODUCTION

Less invasive THR (LITHR) has been criticized by many authors for having a steep learning curve and increased complication rate.

PURPOSE

The current study assesses complication rates of anterolateral LITHR in three different clinical settings.

METHODS

Phase I was the initial learning curve of experienced academic surgeons and staff, comparing the first 49 LITHR in selected patients to 35 traditional THR. In Phase II, inexperienced residents, under the direction of experienced staff, performed 46 consecutive LITHR in nonselected patients. In Phase III, an experienced surgeon performed the first 50 nonselected LITHR at a new hospital with no previous LITHR experience. Surgical complications were recorded for all patients. Minimum followup was 2 years.

RESULTS

In Phase I, no fractures, nerve palsies, dislocations or delayed wound healing occurred in either group. Only incision length was significantly different. In Phase II, a tapered stem was used in all cases, and results were compared to the LITHR tapered stem cohort (n=18) in Phase I. Surgical time was significantly shorter (average 22 minutes), and proximal calcar fracture occurred in 6% (vs 0%in Phase I, but similar to a previous report on this stem). There were no dislocations, nerve palsies or delayed wound healing. In Phase III, compared to the Phase II, there was no difference in BMI, blood loss, surgical time, cup position, or length of stay. Again, no dislocations, nerve palsies or delayed wound healing.occurred. Patients were significantly older.

CONCLUSIONS

We did not see an increase in complication rates or steep learning curve of LITHR.

A9-2

COMPARISON OF MINIMAL INVASIVE TOTAL HIP REPLACEMENT VERSUS STANDARD TOTAL HIP REPLACEMENT WITH CONVENTIONAL JIGS-STUDY OF REVELATION HIP SYSTEM

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PURPOSE

To compare the early result of minimum invasive surgery (MIS) with standard jigs to non-MIS procedures with use of Revelation Hip System (Encore).

MATERIALS AND METHODS

From June 2004 to December 2005, 40 primary total hip arthroplasty of 39 patients were performed. Among the 40 hips, 22 were performed by MIS (less than 10cm) and 18 hips were performed by non-MIS. The surgeries were performed by only 2 surgeons (YT, NW). Each surgeon decided whether MIS was applicable on each patient or not. Antero-lateral approach (modified Dall) was applied for all surgeries. The same rehabilitation program was applied on both groups postoperatively.

RESULT

The applicability of MIS was significantly less in male patients (Male 2/8, female 20/32). There was a relationship between patients' height and the length of skin incision ($p<0.05$). No significant difference between two groups was proved in CRP, CPK and D-Dimmer (CRP: 14.2/12.5mg/dl, CPK: 396.7/368.1mg/dl, D-Dimmer: 14.2/5.2mg/dl). Both of intraoperative blood loss and operation time were less in MIS group (blood loss 529.4ml vs. 766.7ml, operation time 101min vs. 115min). The days until the patient could do Active SLR were 17.4 in MIS group and 22.8 in non-MIS group and hospital stay days were 22.6 vs. 29.2. But no significant differences were proved in hospitalization. On roentgenografic findings, the inclination of acetabular cup was 42.7 degree in the MIS group versus 40.9 in the non-MIS group and no significant difference was found.

CONCLUSION

At the patient selection, each surgeon decided MIS due to patient's heights. In the present study, intra-operative hemorrhage and operation time were significantly less in MIS group. But in another situation, no significant difference was found for example in serum CRP, CPK and D-Dimmer levels.

A9-3

PROSPECTIVE COMPARISON STUDY OF CLINICAL DATA BETWEEN THE MINIMAL INCISION AND CONVENTIONAL INCISION IN TOTAL HIP ARTHROPLASTY

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OBJECTIVE

Minimal incision method in total hip arthroplasty (THA) is reported to be less invasive. To determine whether minimal incision THA is a feasible surgery, we investigated on prospective comparison study of clinical data between the minimal incision and conventional incision in total hip arthroplasty.

MATERIALS AND METHODS

Between May 2003 and January 2004, 20 hips were selected from 20 patients of osteoarthritis without any complications. Ten hips were used conventional incision (group C), 10 hips used minimal incision (group M) in primary cementless THA. Gender are group C: 1 male, 9 female, group M: 3 male, 7 female. Ages are group C: average of 63.1 (56-75), group M: average of 66.4 (55-76). Length of incision for group C: average of 13.8 (11-17) cm, group M: average of 7.5 (6-9) cm. The same anesthesia, NSAID, as well as critical pathway were used on both groups. No complication was noted on both groups. The minimal incision performed is what made only skin incision smaller compared with conventional incision method. On all THA cases, St Nabor cup and Duetto SI stem by Bauer's transgluteal approach was used.

RESULTS

Operation time for group C: average of 119.9min, group M: average of 126.5 min. Estimated blood loss for group C: average of 772ml, group M: average of 796 ml. Postoperative cup abduction angle for group C: average of 42.9 degrees, group M: average of 41.5 degrees. Hospital stay for group C: average of 23.4 days, group M: average of 22 days. Preoperative Japanese Orthopedic Association (JOA) hip score for group C: average of 52.5 points, group M: average of 52.2 points. Postoperative JOA hip score at discharge for group C: average of 79.4 points, group M: average of 79.5 points. So far, there was no significant difference in two groups. For complications, we have had a non-displaced fracture of greater trochanter and femoral nerve palsy in group M, and a heterotopic ossification in group C.

CONCLUSION

This study demonstrates that minimal incision THA had no significant difference compared with conventional incision THA in prospective comparison study of clinical data. The minimal incision THA in our procedure is a feasible surgery.

A10-1

IN VIVO ANALYSIS OF KNEE KINEMATICS FOR SUBJECTS IMPLANTED WITH A HIGH FLEXION TKA

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The objective of this study was to determine the in vivo kinematics for subjects implanted with a high flexion (HF) Total Knee Arthroplasty (TKA). Seventy-two subjects were asked to perform maximum weight-bearing flexion, while under fluoroscopic surveillance. Thirty-two subjects (two surgeons) were implanted with a Sigma Posterior Stabilised (PS) Rotating Platform (RP) HF TKA (SRP), 20 with a Legacy PS fixed bearing (FB) HF TKA (LFB) and 20 with a Legacy PS RP HF TKA (LRP). The average weight-bearing flexion was 124.8, 102.1, 117.3 and 125.4 degrees for subjects having a SRP (study 1), SRP (study 2), LFB and LRP TKA, respectively. The average amount of posterior femoral rollback was -5.9, -2.6, -5.1 and -8.4 mm, for subjects implanted with a SRP (study 1), SRP (study 2), LFB and LRP TKA, respectively. The average amount of axial rotation was 3.8, 6.1, 6.5 and 5.4 degrees, for subjects implanted with a SRP (study 1), SRP (study 2), LFB, and LRP TKA, respectively. Subjects having a SRP (study 2) experienced statistically less weight-bearing range-of-motion than the subjects in the other three studies ($p<0.05$). The subjects having a SRP (study 1), LFB and LRP TKA experienced statistically similar results. The results from this study seem to suggest that surgical technique does play a significant role in range-of-motion ($p<0.05$) and that subjects implanted with a high flexion TKA, in three groups tested, did achieve a benefit.

A10-2

DOES HIGH FLEXION TKA IMPROVE THE MECHANICAL BEHAVIOUR AT HIGHER FLEXION ANGLES AND DOES IT MAINTAIN THE GOOD MECHANICAL PERFORMANCE OF STANDARD TKA AT NORMAL FLEXION ANGLES?

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INTRODUCTION

There is a growing demand for high flexion Total Knee Arthroplasty (TKA), especially in Asian countries because of cultural or religious reasons. However, the question is: does high flexion TKA improve the mechanical behaviour at higher flexion angles (>120 degrees) and does it maintain the good mechanical performance of conventional TKA at normal flexion angles (<120 degrees)? In this study, the new high flexion Sigma RP-F is compared with the conventional Sigma RP.

MATERIALS AND METHODS

Two identical dynamic finite element models of the knee joint were created: one for the Sigma RP-F and one for the Sigma RP. Both models consisted of a femur, tibia, fibula, patella, patella tendon, quadriceps tendon and the prosthetic components. The patella tendon and quadriceps tendon were modelled as actual bands. The TKAs were Rotating Platform (RP) and Posterior Stabilized designs. Elasto-plastic properties were used to model the polyethylene. The tibia was loaded at ankle level with a ground reaction force of 350N. The proximal ends of the quadriceps tendon were constrained. The length of the quadriceps tendon was increased uniformly which resulted in flexion (70 degrees to max. flexion), due to the ground reaction force.

We considered the polyethylene insert as the weakest part of a TKA. Therefore, the peak contact stresses and the PE insert volume loaded above the yield stress (yield volume) were calculated during the dynamic simulation of squatting. These outcome parameters were calculated separately for the dishes and the post of the insert. A posterior tibio-femoral contact position is a requisite for high flexion. Hence, the contact positions were also calculated during the simulation.

RESULTS

The high flexion Sigma RP-F showed a lower maximum yield volume within the high flexion range as compared to the conventional Sigma RP. The peak contact stresses were lower at the dish, but slightly higher at the post. In normal flexion, the yield volume and peak contact stresses were very similar for the Sigma RP and Sigma RP-F. However, both the Sigma RP and Sigma RP-F were more at risk in high flexion: both the yield volume and the contact stresses were higher in high flexion as compared to normal flexion. The Sigma RP showed a more posterior contact location between 105º and 140º.

DISCUSSION AND CONCLUSION

This study suggests that the RP-F design adaptations are effective, as the RP-F had a better performance in high flexion than the RP. Furthermore, these design adaptations did not seem to have adverse effects within the normal flexion range. However, the design changes could not prevent that, due to the higher loads at higher flexion angles, it is more at risk than TKA which is only subjected to activities in normal flexion.

A10-3

IN VIVO COMPARISON OF KINEMATICS FOR SUBJECTS HAVING A NEXGEN HIGH FLEX OR SCORPIO SUPERFLEX PS TKA

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One area that has received significant attention as a contributor to TKA failure is polyethylene wear. A better understanding of knee kinematics is important to explain the premature polyethylene wear failures observed, especially as it relates to the factors that contribute to condylar lift-off and edge loading. The objective of the current study was to determine the *in vivo* kinematics for subjects implanted with either the Zimmer NexGen High Flex PS TKA or the Osteonics Scorpio Superflex PS TKA. Both of which were designed to allow for increased knee flexion.

In vivo kinematic patterns were determined for 20 subjects, 10 in each group, who were implanted with one of the two PS TKA types. Under fluoroscopic surveillance, each subject was asked to perform a weight-bearing deep knee bend to maximum flexion. The fluoroscopic video was digitized and frames were captured at 0°, 30°, 60°, 90° and at their maximum amount of knee flexion and analyzed for their kinematics. The contact position between the femur and the tibia was determined using a 3D model fitting technique. Once the 3D components were fit, the medial and lateral femorotibial contact positions were determined with respect to the midline of the tibia in the sagittal plane. Next, in the transverse plane each knee was evaluated to determine the amount of axial rotation. The frontal view was then used to assess condylar lift-off by measuring the distances from the medial and lateral condyles to the tibial plateau.

During the full motion cycle, on average, the subjects having a NexGen High Flex PS TKA experienced -5.0 and -1.3 mm of posterior femoral rollback of the lateral and medial condyle compared to -3.1 and -1.8 mm for the Scorpio Superflex PS TKA. All ten subjects having a NexGen High Flex PS TKA experienced normal axial rotation patterns compared to 8/10 Scorpio Superflex PS TKA subjects. The NexGen High Flex PS TKA subjects experienced an average of 5.0 ± 4.8° of axial rotation compared to 2.6 ± 9.4° for the Scorpio Superflex PS TKA subjects. Five out of ten subjects having the NexGen High Flex PS TKA experienced condylar lift off greater than 1mm compared to 6/10 subjects with a Scorpio Superflex PS TKA. The maximum amount of condylar lift off was 2.1 mm for the NexGen High Flex PS TKA compared to 2.5 mm for the Scorpio Superflex PS TKA. The average amount of weight bearing range-of-motion was 110° for the subjects having a Nexgen High Flex PS TKA compared to 95° for subjects with a Scorpio Superflex PS TKA. Nine of the ten subjects having a NexGen High Flex PS TKA experienced at least 100° of weight-bearing range-of-motion compared to 3/10 subjects with a Scorpio Superflex PS TKA.

In conclusion, on average and subject-to-subject comparisons revealed that the NexGen High Flex PS TKA experienced greater posterior femoral rollback, more normal axial rotation patterns, less condylar lift-off and greater range-of-motion. It is possible that the implant geometry contributed to the differences in results.

A10-4

COMPARISON OF HIGH FLEXION TKA PATELLOFEMORAL KINEMATICS

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Patellofemoral complications remain one of the major causes of revision surgery and it is hypothesized that altered kinematics in deep flexion could lead to higher forces. Therefore the objective of this project was to study the kinematics of the patella for two high flexion designs – the Nexgen PCR TKA and the LPS Flex PS TKA and compare them with that of normal knees.

Thirty subjects, ten in each group, were studied using video fluoroscopy in the sagittal plane while flexing their knee from full extension to a squatting position. The fluoroscopic video was digitized and individual frames at 0º, 30º, 60º, 90º and 120º of flexion were analyzed for the patellofemoral contact point, patellar tilt and separation. Patellar contact point superior to the patellar mass center was considered positive. The patellar tilt angle was defined as the angle between the patellar axis and the longitudinal tibial axis. Patellar separation was determined by measuring the distance between the most anterior aspect of the femoral component and the most posterior aspect of the patella.

The average weight-bearing flexion was 116° (±12.86°), 117° (±9.52°) and 135° (±17.76°) for subjects having PCR TKA, LPS TKA and normal knee, respectively. In all the three groups the contact point moved from inferior to the superior direction and at maximum flexion had an average value of 7.2 (±2.6) mm, 8.3 (±3.8) mm and 7.9 (±2.6) mm for PCR TKA, LPS TKA and normal knee, respectively. However, during the early part of flexion, the contact point for the normal knee was found to be inferior to that of the implanted knees. At full extension the average location of the contact point for the normal knees averaged -12.2 (±3.3) mm while for the implanted knees averaged -2.6 (±3.5) mm and -1.1 (±4.8) mm for PCR TKA and LPS TKA, respectively. The implanted knees had similar nature of patellar rotation as that of the normal knees. At full flexion, the tilt angle for normal knees was 36.6°(±7.3°), while subjects having the implanted knees averaged 28.9°(±5.5°) and 23.6°(±5.3°) for PCR TKA and LPS TKA, respectively.

In conclusion, subjects having either implanted knee experienced similar kinematic patterns. Also, the nature of variation of the translation and rotation of the patella was found to be similar to those observed in normal knees, though the magnitudes were smaller. Also, subjects having a TKA demonstrated separation of the patella when the knee was fully extended. It is assumed that this phenomenon is due to the more posterior contact of the femoral condyles at full extension.

A10-5

KINETIC PERFORMANCE COMPARISON FOR TRADITIONAL AND HIGH FLEXION TKA

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Recently, patients are requesting TKAs that allow for higher degrees of knee flexion and the surgeon to implant them using smaller incisions. Therefore, manufacturers are now developing high flexion type TKA that are not radically different from the more traditional ones but incorporate subtle changes in the geometry of the femoral and the polyethylene component radii to facilitate higher amounts of flexion. Some studies have demonstrated that they achieve higher amounts of flexion. However, failure, in the form of wear of the polyethylene insert, still reigns as the major limiting factor in modern TKAs. As a result, analyzing the contact forces and contact stresses experienced in these types of implants is of great importance. Therefore, the purpose of this study was to compare the in-vivo kinetic performance of traditional and high flexion TKAs.

For this study, 17 subjects were analyzed under fluoroscopic surveillance while performing a deep knee bend activity. Five of the subjects were implanted using a traditional fixed bearing TKA, five with a traditional mobile bearing implant and seven with a high flexion fixed bearing type implant. In-vivo kinematics for the subjects were analyzed using a 3D to 2D image registration technique and were input in an 3D inverse dynamics rigid body analysis mathematical model in order to generate the contact forces at the femoral and polyethylene interface. Based on the transformation coordinates obtained from the previously described registration technique the CAD models of the femur and polyethylene were assembled and the interface area between the two was measured. This interference area was assumed to be the contact area. Finally, the contact pressure was defined as the ratio of the contact forces and the contact areas.

The medial contact forces for all the implants were found to be similar ranging from about 0.5 BW at full extension to about 2.7BW at full flexion. The high flexion TKA however experienced slightly higher values of lateral contact forces reaching a value of 1.25BW at full flexion compared to the traditional TKAs, which had a maximum value of 0.85BW at full flexion. Interestingly, however, the high flexion TKA was able to maintain a high amount of contact area throughout the flexion cycle when compared to those of the traditional bearings. This was observed markedly during the later half of flexion, where there was a reduction in the contact area for the traditional bearing TKAs but an increase in contact area for the high flexion design TKA. As a result the high flexion TKA had significantly lesser magnitudes of contact pressures than the traditional TKA types on both the condyles.

In conclusion this study reflects that the high flexion designs have similar nature of contact forces compared to the traditional designs. However, the high flexion design is able to maintain higher amount of femoro-tibial conformance resulting in lower contact pressures and therefore seems to offer and advantage in this regard.

A10-6

DEEP FLEXION KINEMATICS IN PCL-RETAINING AND –SACRIFICING KNEES WITH THE SAME IMPLANT DESIGN

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There is strong interest to provide patients receiving total knee arthroplasty (TKA) with large ranges of functional knee flexion. Previous studies have identified geometric and kinematic factors contributing to knee flexion, including a posterior femoral position on the tibia, posterior condylar offset, and posterior tibial slope. These factors can be incorporated into implant designs and surgical techniques in various combinations to emphasize different factors. An interesting aspect of these efforts will be the robustness of the resulting design – that is, will the kinematic or functional result be consistent when patient and surgical factors vary widely. The purpose of this study was to evaluate the in vivo flexion performance of a single implant design in patients whose posterior cruciate ligament (PCL) was either meticulously maintained or summarily excised.

Twenty-eight knees in twenty patients were observed using single-plane fluoroscopy during maximum flexion kneeling and lunge activities. Twenty knees (twelve patients) received arthroplasty with full maintenance of the PCL, including a bone block on the proximal tibial surface (PCL+ group). Eight knees (seven patients) received arthroplasty with full resection of the PCL (PCL- group). All knees received a fixed-bearing TKA with an asymmetric tibial bearing having a sagittally curved medial compartment and a lateral compartment fully congruous with the lateral condyle in extension (approximate anterior cruciate ligament substitution). 3D knee kinematics were determined using model-based shape registration techniques.

For the kneeling activity, mean implant flexion was 124°±11° for the PCL+ knees and 121°±17° for the PCL- knees ($p>0.05$), mean tibial internal rotation was 10°±4° for the PCL+ knees and 9°±3° for the PCL- knees ($p>0.05$) and tibial valgus was -1°±1° for the PCL+ knees and 2°±4° for the PCL- knees ($p=0.003$). Medial contact locations during kneeling averaged -2mm±4mm for the PCL+ knees and -1mm±2mm for the PCL- knees ($p>0.05$), and lateral contact location averaged -10mm±4mm for the PCL+ knees and -7mm±1mm for the PCL- knees ($p>0.05$).

For the partial weight-bearing lunge activity, mean implant flexion was 120°±11° for the PCL+ knees and 121°±21° for the PCL- knees ($p>0.05$), mean tibial internal rotation was 11°±4° for the PCL+ knees and 8°±3° for the PCL- knees ($p>0.05$) and tibial valgus was -1°±1° for the PCL+ knees and 2°±2° for the PCL- knees ($p=0.0002$). Medial contact locations during kneeling averaged 0mm±4mm for the PCL+ knees and -4mm±3mm for the PCL- knees ($p=0.04$), and lateral contact location averaged -8mm±4mm for the PCL+ knees and -9mm±4mm for the PCL- knees ($p>0.05$).

There was no difference in implant flexion between PCL retaining and sacrificing knees, and both groups had knees exhibiting more than 145° implant flexion (~155° skeletal flexion). There also were no statistically significant differences in tibial rotation or lateral condylar contact locations. There were differences in tibial valgus for both activities. The PCL- knees exhibited a tendency for the medial compartment to “book open” with flexion beyond 130°, consistent with loss of PCL function. Based on this small cohort comparison, it appears that robust flexion performance and knee kinematics can be obtained with a fixed-bearing TKA design.

A10-7

PATELLOFEMORAL COMPLICATIONS IN TOTAL KNEE ARTHROPLASTY: CLINICAL AND RADIOGRAPHIC RESULTS OF 145 CONSECUTIVE CASES USING A THIRD GENERATION POSTERIOR CRUCIATE SUBSTITUTING KNEE PROSTHESIS

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INTRODUCTION

Incidence of patellofemoral complications in total knee arthroplasty (TKA) has been reported to be as high as 50 percent, accounting for a significant reoperation rate. The purpose of this study was to assess the outcomes of TKA using a third generation prostheses that specifically addresses normal kinematics of the patellofemoral joint.

METHODS

One hundred and forty-five consecutive TKA (in 123 patients) performed by a single surgeon were included. The employed prosthesis was a posterior cruciate substituting knee with a deepened and posteriorly elongated trochlear groove designed to provide for smooth patella tracking through a full range of motion. The patellar button consists of an oval configuration with an offset dome. Radiographic and clinical (with patellofemoral specific questionnaires) data were analyzed.

RESULTS

There were 49 males and 74 females included in this study whose mean age was 67 years (range, 42-86). The TKA's were assessed at a mean follow-up of 49 months (range, 24-89). There were no reoperations for patellofemoral problems, aseptic loosening, or deep infection. Knee Society Scores significantly ($p<0.05$) improved from preoperative evaluations. Patients reported a significant ($p<0.05$) improvement in anterior knee pain and independent chair rise. A lateral release was performed in 3 knees (2 percent).

CONCLUSION

The lateral release rate in this series is low compared to the current literature (up to 15%). The low incidence of patellofemoral complications indicates that appropriate surgical technique along with design changes, with particular attention to the trochlear design and patellofemoral contact throughout full flexion, have achieved their intended purpose.

Lifetime Achievement Award

A11-1

WEAR ADVANTAGE OF NOVEL ROTATING BEARING KNEE – AN IN-VITRO STUDY

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OBJECTIVE

The Optetrak® RBK™ is a novel rotating bearing knee (RBK) characterized by a unique distal bearing shaped like a "wave," which is intended to reduce the risk of peg wear by shielding the tibial insert central peg from loading. The purpose of this study was to evaluate the wear performance of this knee relative to its clinically well-proven fixed-bearing knee version (objective 1) and compare it to other RBKs on the market using the same protocol (objective 2).

MATERIALS AND METHOD

The general procedure was based on ISO 14243-1 with the exception of the fluid test medium formulation. Three Optetrak® RBK™ (Exactech, Inc., Gainesville, FL.) components were used for the wear test. A previous wear test that included two Optetrak® PS fixed bearing knees provides a solid comparison between the Optetrak RBK™ and its fixed bearing version. Finally, the laboratory performing this study (Endolab, Rosenheim, Germany) shared individual wear rates for all of the rotating bearing knee systems that they tested (n=16) using the same protocol, which simulated more than one degree of axial rotation between the femoral and tibial components (n=9). For confidentiality reasons, the laboratory did not share the trademark for these systems.

RESULTS

After correcting for fluid test medium absorption, the net wear rate averaged 2.11 ± 0.47 milligrams per million cycles (mg/Mc) (range 1.69 to 2.92 mg/Mc) and 3.00 ± 0.47 mg/Mc (range 2.67 to 3.33 mg/Mc) for the Optetrak® RBK™ and the Optetrak® PS, respectively. No significant difference between these two tests ($P > 0.05$) could be found using Student's t-Test.

The mean wear rate Endolab reported for the historical rotating bearing knee systems that exhibited more than one degree of axial rotation between the femoral and tibial components was 6.65 mg/Mc (a range of 2.42 to 16.7 mg/Mc), which was higher than the Optetrak® RBK™.

DISCUSSION

In addition to the low wear rate, low kinematic variation in response to the simulated cycle between the three Optetrak® RBK™ stations was observed. Because the surface contact between the tibial insert and tibial tray is controlled (i.e. along the deepest portion of the wave), the torque required to initiate rotation at the lower bearing is predictable.

A post-test visual analysis of the Optetrak® RBK™ tibial inserts showed that all of these exhibited identical contact patterns on the second bearing. The extent of wear on the central peg and tibial tray bore was minimal, as evidenced by microscopic visual examination. This is unusual for rotating bearing knee designs with flat second bearings, which typically demonstrate large wear patterns along the anterior face of the central peg under anterior-posterior force application. This concept of a wave-shaped bearing promotes the reduction of wear caused by contact between the central peg and tibial tray bore in prostheses associated with a flat tibial tray (when tested on a knee simulator).

A11-2

DESIGN SPECIFIC INCREASE IN RANGE OF MOTION WITH THE PFC SIGMA RP-F TKR: A MATCHED PAIR STUDY

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A11-3

IN VIVO KINEMATICS OF NEXGEN LPS-FLEX MOBILE BEARING TKA IN DEEP KNEE BENDING MOTION

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The purpose of this study was to evaluate the kinematics of PS mobile bearing total knee arthroplasty in weight-bearing deep knee bending motion using 2D/3D resistration technique. Nine subjects were implanted with NexGen LPS-FLEX mobile bearing total knee arthroplasty. Diagnoses were osteoarthritis in 3 subjects and rheumatoid arthritis in the other 6 subjects. Mean age at the time of fluoroscopic surveillance were 59.9 ±6.1 years (range, 52-72 years). Mean postoperative knee society knee score was 91.3±8.2 points(75-100 points) and mean postoperative knee society function score was 80.6±7.8 points (65-90 points).Each subjects were examined during a deep knee bending motion using the sagittal plane fluoroscopic images. Femorotibial motion was determined using 2D/3D resistration technique, which uses computer-assisted design models to reproduce the position of femoral and tibial components from single-view fluoroscopic images. The average range of motion was 117º. The average femoral component demonstrated 12.5º external axial rotation. On the average, the medial femorotibial contact position moved 3.8 mm posteriorly from -10º to 10º flexion, 7.6 mm anteriorly from 10º to 90º flexion, and then 10.4 mm posteriorly from 90º to 130º flexion. The lateral femorotibial contact position moved 6.0 mm posteriorly from -10º to 20º flexion,0.0 mm from 20º to 80º flexion, and then 8.8 mm posteriorly from 80º to 130º flexion. The kinematic pathway was an early rollback from -10º to 20º flexion(Fig 1), the external axial rotation in lateral pivot pattern from 20º to 80º flexion(Fig 2), and a bicondylar rollback from 80º to 130º flexion(Fig 3). In this study, femoral component demonstrated a lateral pivot pattern that were not observed a normal knee from 20º to 80º flexion. With more than 80º flexion, femoral component demonstrated a bicondylar rollback. We hypothesized that the kinematics of NexGen LPS-FLEX mobile bearing total knee arthroplasty in deep knee bending motion were not similar to the normal knee.

Fig 1

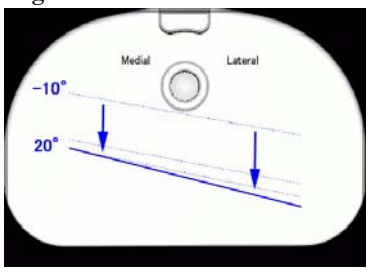


Fig2

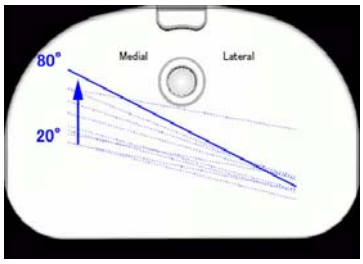
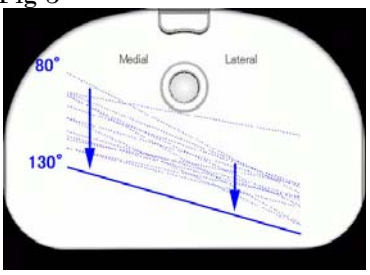


Fig 3



A12-1

INSTABILITY OF TOTAL KNEE REPLACEMENTS IMPLANTED WITH A LIGAMENT BALANCING INTRAOPERATIVE TENSOR

Raj K. Sinha, MD, PhD

INTRODUCTION

The most common reason for early revision after total knee replacement (TKR) is instability. Early techniques required ligament balancing, often with an intraoperative ligament tensor, which is rarely used by modern surgeons.

PURPOSE

The current study describes a ligament balancing technique using an intraoperative tensor and reports early instability rates.

METHODS

In the first phase of this study, a V-STAT tensor (Zimmer,Inc) was utilized to perform TKRs on 6 cadaver knees. Medial and lateral collateral ligament strain throughout the range of motion was measured pre- and post-TKR. The amount of tension that most closely replicated pre-TKR collateral ligament strain was determined and then utilized to perform 127 consecutive TKRs on 111 varus and 16 valgus knees. A median parapatellar approach was utilized in all cases. The rate of lateral release, patellar instability, manipulation and femorotibial instability were recorded.

RESULTS

The cadaver study revealed that 40 lbs of tension most closely replicated the normal collateral ligament strain pattern. 4/16 (25%) valgus knees and 12/111 (9.7%) varus knees required lateral retinacular release. At average 2.3 year follow-up, one knee had lateral dislocation of the patella due to deep wound dehiscence. 2 (1.6%) knees had femorotibial instability requiring revision for correction. 3 (2.5%) additional knees required manipulation within 6 weeks.

CONCLUSIONS

The use of a ligament tensor resulted in excellent clinical results with a low incidence of instability.

A12-2

COMPUTER ASSISTED ORTHOPAEDIC SURGERY WITH LIGAMENT BALANCING TECHNIQUE USING AN INTERNAL TENSIONOMETER LOWERS MANIPULATION RATE IN TOTAL KNEE REPLACEMENT

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INTRODUCTION

There are multiple potential causes of the need for manipulation after total knee replacement. Several factors have been associated with the need for manipulation including pre-operative range of motion, length of stay, inadequate soft tissue balance and patient related factors. We have postulated that computer assisted surgery (CAS) using a ligament balancing protocol and a soft tissue tensionometer should generate a decrease in the manipulation rate compared to the conventional total knee replacement in a group of patients undergoing total knee replacement with mobile bearing knees.

METHOD

This study represents a single surgeon series of 442 computer assisted primary total knee replacements using mobile bearing knees and performed with a ligament balancing protocol and a soft tissue tensionometer compared with 179 consecutive knees performed with traditional intramedullary instruments without the benefit of ligament balancing

All patient data was collected in a prospective computerized data base and retrospectively reviewed. Patients were examined pre-operatively, and at the six week post operative interval visit and at the three month visit. The decision to perform manipulation was based on the examination results at the six week post operative interval visit. If the patient achieved less than 90 degrees of flexion at this visit and wished to proceed with manipulation to improve range of motion and decrease arthrofibrosis, then manipulation was performed within a week of the diagnosis of arthrofibrosis or decreased range of motion.

RESULTS

Prior to the institution of the tensionometer for ligament balancing, the total manipulation rate in conventional mobile bearing knees performed with intramedullary instruments was 16% or 28 out of 179 knees. After the introduction of ligament balance as a part of computer assisted total knee replacement, the manipulation rate dropped to 7% or 29 out of 442 consecutive mobile bearing knees. Interestingly, the rate of manipulation in computer assisted total knee replacement prior to the addition of the tensionometer was 14%, with manipulation occurring in 14 or 97 cases.

Overall there were no differences in the group regarding overall range of motion, Knee Society scores, and pain scores in either group. However there was a definite decrease in earlier functional recovery of Knee Society scores in the group after the tensionometer with improvement that was persistent at the three month interval visit.

CONCLUSION

We conclude that computer assisted total knee replacement surgery with use of the ligament balance protocol and the use of an internal tensionometer leads to a decreased manipulation rate and improved Knee Society scores in the first three months after total knee replacement surgery with a mobile bearing knee replacements. There was also no bearing spin out occurring in the conventional group or the group treated with the ligament balancing protocol and the tensionometer.

A12-3

TOTAL KNEE ARTHROPLASTY FOR VALGUS DEFORMITY CORRECTED WITH THE PIE-CRUSTING TECHNIQUE: A FIVE TO TWELVE YEAR FOLLOW UP STUDY

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INTRODUCTION

Correction of fixed valgus deformity presents a challenge in primary total knee arthroplasty (TKA). The aim of our paper was to retrospectively review a cohort of primary TKA performed in patients with preoperative valgus knees using the pie-crusting technique.

METHODS

Sixty-five patients (73 knees) with preoperative alignment greater than 10 degrees of valgus were operated between January 1994 and September 2000. The primary diagnosis was degenerative osteoarthritis in 62 knees, inflammatory arthritis in 10, osteonecrosis of lateral femoral condyle in one. Fifty-five knees (75%) were available for follow up at 94 months (range 60-144). With the pie-crusting technique the posterolateral capsule was incised at the level of the tibial osteotomy and inside-out multiple stable incisions were made using a # 15 knife blade in the contracted lateral soft tissues (particularly in the ITB and the lateral collateral ligament) until the deformity was corrected using laminar spreaders in extension. The popliteus tendon was always preserved to limit the risk of posterolateral flexion instability. Various types of implants were used: IB-II (20%), LPS (22%), MBK (54%) and CCK in only 4%. At follow-up all patients were evaluated using the Knee Society scores, the Knee Arthroplasty Patellar Score, a radiographic study which included weightbearing long films and also stress x-rays (telos) to evaluate gaps configuration.

RESULTS

At follow-up the average Knee Society clinical score improved from 38 points preoperatively to 90 points postoperatively, and the average functional score improved from 43 to 82 points. Postoperatively results were excellent in 60%, good in 24%, fair in 12% and poor in 4% of cases. A transient postoperative peroneal nerve palsy was observed in one patient. The mechanical axis was 0±2° in 37 (67 %) knees, 3° to 5° of valgus in 6 (11%), 3° to 5° of varus in 10 (18%), more than 5° of varus in 2 (4%) knees. There was one (1.8%) case of instability which refused further treatment. Stress views showed gaps symmetry (0±2 mm) in 59%, minor asymmetry (3-5 mm) in 36%, and asymmetry more than 6 mm in 5% (3 knees) of the cases. There was one case of asymptomatic tibial osteolysis, and one failure due to aseptic loosening of the femoral component, which was revised.

CONCLUSIONS

The pie-crusting technique is a reliable method to correct fixed valgus deformity in patients undergoing TKA, with a low complication rate and excellent mid-to-long terms results.

A12-4

THE RELATIONSHIP BETWEEN INTRA-OPERATIVE SOFT TISSUE BALANCE AND SHORT TERM POST-OPERATIVE RESULTS IN PS-TYPE TKA

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PURPOSE

The aim of this study is to investigate the relationship between intra-operative balance and short term post-operative ROM and stability in Posterior-Stabilized type Total Knee Arthroplasty(TKA).

MATERIALS AND METHODS

Forty-three patients (9 male and 34 female, average 71 y/o at operation), who had taken TKA in our hospital between 2004 April to December, were included in this study. After cutting independently and balancing manually, 'Balance' and 'Gap' were measured with seesaw type balancer. 'Gap' at 0°(EG), at 90°(FG) of knee flexion and 'Balance' at 0°(EB), at 90°(FB) with balancer were noted. With these data, Joint tightness (JT: Gap/ width of implants) was calculated at 0°(EJT) and 90°(FJT). Postoperative evaluations were performed at 3 weeks post-operatively. In addition to measuring postoperative ROM, varus and valgus stress X-P at 0°with arthrometer and ‘Kanekasu’s Epicondylar view’ at 90° were performed. Varus angle (VRA), valgus angle (VLA) and inclination angle (IA) were obtained. Correlation of intra-operative 'Balance'&'Gap' and post-operative ROM & stability were investigated.

RESULTS

Mean postoperative flexion angle (FA) was 106°, and mean flexion achievement rate (AR: post-operative FA / preoperative FA ×100) was 96.1%. Intra-operative 'Balance' and 'Gap' were as follows; EB 2.38±4.25°, FB -0.07±6.74°, EG 22.0±5.9mm, FG 29.0±3.3mm, EJT 1.07±0.18, FJT 0.94±0.19. ROM was not correlated with EG, FG, EJT and FJT. Postoperative stabilities were as follows; VRA 5.97±3.69°, VLA 5.50±3.23°, IA 0.94±4.88°. VRA+VLA were correlated with post-operative ROM.

CONCLUSIONS

There are many reports about soft tissue balance of TKA, however the relationship between intra-operative balance and post-operative results still remains unknown. Our study revealed that intra-operative 'Balance' and 'Gap' were not correlated with post-operative ROM, but when the components were inserted under appropriate tension, it was suggested to be correlated with lateral instability(VRA+VLA).

Although so-called "Same rectangular" has been thought the ideal balance, the physiological lateral join laxity was proved by some recent researches. Furthermore, since joint stiffness differs according to flexion angle, it is thought to be necessary to take into consideration not only gap length but also gap tension.

Our study has some limitations as follows. Our evaluations were performed only at 3 weeks after operation, and they were static and two-dimensional evaluations. In future, to pursue a change of stability with time and dynamic and three-dimensional analysis should be needed. Although there is an objection in applying PS-type TKA, ACL and PCL deficit knee, to physiological conditions, it is thought to need to pursue more ideal balance in consideration of anatomical lateral joint laxity.

B1-1

THE EARLY U.S. EXPERIENCE OF REVERSE SHOULDER ARTHROPLASTY: INDICATIONS, TECHNIQUE, AND RESULTS

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INTRODUCTION

To date, rotator cuff arthropathy (RCA) remains a difficult clinical entity with no uniformly excellent surgical option. The recent FDA approval of reverse prosthetic technology offers a promising treatment modality for this difficult problem. We discuss technical considerations and early results of the first 462 consecutive patients treated with the Reverse Shoulder Prosthesis (RSP) (Encore Medical, Austin, TX, USA).

MATERIALS

From November 2002 through March 2005, 462 RSP procedures were performed for primary RCA or a failed prosthetic replacement with rotator cuff deficiency. The study was a multi-center, FDA approved Investigational Device Exemption clinical trial of the Reverse Shoulder Prosthesis. The device has since been FDA approved. Patients were assessed pre-operatively with pain and range of motion scores. Pre-operative pain as assessed on a 1-10 scale averaged 8.7 (Range= 6-10, SD= 1.41). Pre-operative forward elevation was 53.1 degrees. Patients were assessed for pain, range of motion, and by validated outcomes tools at 3, 6, 12, and 24 months post-operatively.

RESULTS

One year follow-up was available for 312 patients. The mean pain score decreased to 3.2 from a pre-operative value of 8.7. Average forward elevation improved to 93º from a pre-operative value of 53º. The ASES score at one year was 70, compared to a pre-operative mean of 28. There were significant improvements in the pain, function, social, and emotional arms of the SF-36. The complication rate was 14.9% (69/462) which, in addition to problems related to the component, also included infection, hematoma, and unresolved pain. The most common cause of revision was instability of the components.

DISCUSSIONSAND CONCLUSIONS

The early results of reverse shoulder arthroplasty are encouraging, but not without complications. Longer follow-up is necessary to thoroughly evaluate the safety and efficacy of this procedure.

B1-2

GEOMETRIC ANALYSIS OF THE GRAMMONT REVERSE SHOULDER PROSTHESIS: AN EVALUATION OF THE RELATIONSHIP BETWEEN PROSTHETIC DESIGN PARAMETERS AND CLINICAL FAILURE MODES

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INTRODUCTION

In the early 1990's, Paul Grammont designed a novel reverse shoulder prosthesis; this design has been demonstrated to alleviate pain and improve function in patients suffering from cuff tear arthropathy a degenerative condition that was previously treated with unpredictable results. However, the Grammont design is not without complications: the incidence of scapular notching is reported to be high as 50%; the incidence of instability/dislocation is reported to be as high as 10%. Such rates have led surgeons to intentionally implant the prosthesis in a manner not intended by the manufacturers (e.g. fixing the glenosphere with a 15° inferior tilt or with a 4mm distal shift). For these reasons, the purpose of this study is to evaluate the relationship between the Grammont design parameters and the commonly reported clinical failure modes.

METHODS

The Grammont reverse shoulder was geometrically modeled using 3-D computer-aided design software (Unigraphics; UGS, Inc.). An assembly analysis was conducted to quantify the effect of several prosthetic design parameters (humeral neck angle, humeral liner constraint, glenosphere thickness, and glenosphere diameter) on several functionally relevant measurements (Range of Motion (ROM), jump distance, and offset) during simulated humeral abduction/adduction. By implication, the relationship between the aforementioned design parameters and functional measurements will elucidate the failure mechanisms associated with the commonly reported clinical complications for reverse shoulder arthroplasty (scapular notching, dislocation, improper deltoid tensioning, etc…). Specifically, ROM, jump distance, and offset were quantified and compared for each of the following design conditions: as humeral neck angle varied from 130 to 165°; as humeral constraint varied from 0.250 to 0.3125; as glenosphere thickness varied from 17 to 21 mm; and as glenosphere diameter varied from 34 to 44 mm.

RESULTS

The Grammont reverse shoulder (i.e. 155° neck angle, humeral constraint of 0.275, 36x19mm Glenosphere) was observed to impinge inferiorly and superiorly at 35° and 95° abduction, respectively. Assuming no scapular rotation, ROM can be considered to be 60°. Modifying the humeral neck angle by 5° shifts the ROM by 5° (in the same direction) by changing the points of impingement. Modifying humeral neck angle by 5° also changes the offset by 0.25 to 0.5mm (in the same direction). Modifying the humeral constraint by 0.0125 changes the ROM by 4° (in the opposite direction) and the jump distance by 0.5mm (in the same direction). Modifying the glenosphere thickness by 1mm (when the humeral constraint is held constant) changes the ROM by 5° (in the same direction). Modifying the glenosphere diameter by 2mm (when the humeral constraint is held constant) changes the jump distance by 0.5mm (in the same direction).

DISCUSSION AND CONCLUSIONS

The results of this study demonstrate the relationship between each design parameter and functional measurement. Furthermore, the results demonstrate the Grammont impinges on the glenoid inferiorly prior to the patient being able to adduct his/her arm to their side, as is necessary during activities of daily living (ADL). For this reason, the authors conclude that the 155° humeral neck angle makes the Grammont design susceptible to scapular notching and dislocation via inferior impingement. Future reverse shoulder designs should consider shifting the inferior impingement point to a location that permits a ROM resembling a patient's ADL. The application of these relationships is useful in the design of a reverse shoulder prosthesis that maximizes ROM and jump distance, minimizes impingement, and provides sufficient offset to tension the deltoid and maintain the well-documented biomechanical benefits associated with the design.

B1-3

COMPUTER-AIDED SHOULDER ARTHROPLASTY – INITIAL CLINICAL EXPERIENCE

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Computer-aided techniques have been developed to improve implant alignment in hip and knee arthroplasty. Like hip and knee arthroplasty, successful shoulder arthroplasty depends primarily on technique because incorrect component alignment can lead to instability, loosening, and sub-optimal function. We previously reported on a cadaver study in which the accuracy of a novel image-free shoulder navigation system was found to be 2.6º ± 2.5º. The purpose of the present study was to evaluate the clinical safety and utility of the navigation system in an initial cohort of shoulder arthroplasty patients.

Shoulder arthroplasty was performed on thirteen patients by a single surgeon (TBE) using an FDA-cleared image-free navigation system (NaviPro™, Kinamed Navigation Systems LLC, Camarillo, CA, USA). Each patient was operated upon in the beach chair position. After the shoulder joint was exposed, optical trackers were attached to the proximal humerus and the coracoid process. The humeral axis and transepicondylar line were registered. Prior to humeral head resection, the anatomic neck axis (inclination, retroversion) and diameter were measured with the navigation system. The surgeon's intra-operative goal was to resect the humerus along its anatomic axis. The humeral head was resected and the system recorded inclination and retroversion. Native glenoid surface orientation was registered. A navigation tracker was attached to the glenoid reamer. The glenoid was reamed while the navigation system reported inclination and version of the reamed glenoid relative to the native glenoid. Humeral and glenoid components were implanted per standard arthroplasty techniques. The trackers were removed after each procedure and the underlying tissues were inspected for damage.

The trackers were safely and securely attached without damage to bony or neurovascular structures. The trackers held secure during each procedure and did not impede surgical performance or operative site access. The navigation system reported the following anatomic neck measurements for this initial patient cohort: humeral neck retroversion was 29.2º ± 17.7º (range, 55º retroversion to 1º ante version); humeral neck inclination was 136.3º ± 10.9º (range, 112º to 153º); humeral head major diameter was 46.1mm ± 4.9mm (range, 37.3mm to 56.4mm); humeral head minor diameter was 42.9mm ± 3.5mm (range, 36.2mm to 48.6mm). The navigation system reported the following humeral neck resection angles: retroversion was 27.1º ± 16.2º (range, 63º retroversion to 3º ante version); inclination was 136.9º ± 10.7º (range, 114º to 154º). The navigation system reported that the glenoid was reamed relative to the native glenoid in +0.4º ± 3.4º (range, –4º to +10º) of version and –7.6º ± 5.2º (range, –19º to +2º) of inclination.

This initial clinical experience with computer-aided shoulder navigation demonstrates that the procedure is safe and can provide valuable intra-operative measurements. When an anatomic humeral implant system is used, the navigation system provides real-time feedback on the humeral resection as it relates to anatomic neck geometry. The system further provides real-time angulation of the glenoid reamer as it relates to pre-operative glenoid deformity. Future studies are planned to evaluate the accuracy and utility of shoulder navigation in a larger patient cohort and with different implant designs.

B1-4

VALIDATION OF NAVIGATED GLENOID COMPONENT PLACEMENT: AN IN-VITRO PILOT STUDY

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Although conventional surgical instruments for alignment and placement of shoulder prostheses are widely used, there is still room for improvement with regards to placement accuracy. Computer-navigated surgery systems exist for the knee and hip, but at this time none of these cater for the shoulder. We have created a prototype system for the planning and placement of the glenoid component in total shoulder arthroplasty. Our system is based on an existing optical navigation system and several new software components that we have designed. The field of view during surgery is very limited, and therefore the major difficulty in placing the glenoid component is determining the optimal inclination and version. In a previous experimental study [unpublished] we found that an orthopaedic surgeon, experienced in shoulder arthroplasty, can make an error up to 12 degrees in placing a guide wire according to the optimal pose.

The goal of this pilot study is to investigate the accuracy of our system throughout the entire process, from planning a glenoid component to actual placement, represented by drilling a guide-wire.

Five sawbone scapulae (Sawbones Europe AB) were coated with zinc paint and were scanned by CT (0.5x0.5x0.5mm voxels). On the CT-scan for each scapula three guide-wires were planned using our pre-operative planning environment (DeVide, Delft University of Technology). In the OR two fluoroscopy images, oriented approximately 45 degrees with respect to each other, were made of each scapula using a mobile C-arm (Philips Pulsera) and a calibration ring (Brainlab AG). Each fluoroscopic image was registered to the pre-operative CT using in-house developed intra-operative 2D-3D registration software. Once a fluoroscopic image was registered, the pre-operative planning was transferred to the computer navigation system (Brainlab VectorVision) and the planned guide-wire was placed in the scapula using computer navigation. Next, carbon rods (3 mm diameter) were inserted into the drilled holes and each scapula was CT-scanned again. The pre- and post-operative CTs were registered and the intersection of the drilled holes with the glenoid surface and the direction vectors were manually indicated in each CT. The planned and drilled position and orientation of the guide-wires were compared using two measures: the distance between the planned and actual intersection with the glenoid surface and the difference angle between the planned and placed guide-wire direction.

Scapula 1 was excluded because one fluoroscopic image was processed with an incorrect software setting. Scapula 4 was excluded because a human error was made in transferring the planning. For the remaining 3 scapulae (9 holes) the mean distance (absolute value) is 2.04 mm (min 0.21, max 4.6), and the mean difference angle (absolute value) is 1.97 deg (min 0.33, max 4.3).

The numbers presented in this study represent the overall error of the entire process from planning to actual guide-wire placement, which compares favourably to the result obtained by an experienced orthopaedic surgeon using conventional instruments. This study shows that our research on pre-operative planning, intra-operative fluoroscopic registration, and computer navigated placement yields good initial results. We are convinced that this approach will benefit shoulder arthroplasty, therefore we will continue to improve and expand this research.

B1-5
CURRENT STATUS OF TOTAL ANKLE REPLACEMENT

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ABSTRACT
The interest in total ankle arthroplasty (TAA) has never been greater. Recent investigations support our intuition that ankle replacement represents an attractive surgical alternative to arthrodesis for patients with advanced ankle arthritis. Although longer followup is necessary for TAA to displace arthrodesis as the surgical "gold standard", intermediate term results are encouraging. Indications for TAA include primary/post-traumatic and inflammatory arthritis. Contraindications to TAA include avascular necrosis, peripheral vascular disease, neuropathy, active/recent ankle infection, nonreconstructable ankle ligaments, loss of lower leg muscular control and severe osteopenia/osteoporosis. Furthermore, young, active patients with ankle arthritis who may place too great a demand on a TAA, may be better candidates for arthrodesis. Perhaps, more important than in other joint replacement surgery, rigorous patient selection is essential to the success of TAA.

Nine different total ankles that have either stood the test of time, have long term followup or have innovative, biomechanical backed designs are reviewed to demonstrate the recent evolution of TAA. These ankles include the Agility (DePuy, Warsaw, Indiana), Scandinavian Total Ankle Replacement (STAR) (W. Link GmbH & Co., Hamburg, Germany), Hintegra (New Deal SA, Lyon, France), Salto (Tornier S.A.S., Saint Ismier, France),Buechel Pappas (Endotec, South Orange, New Jersey), Mobility (DePuy, Warsaw, Indiana), BOX (Finsbury, Leatherhead, Surrey, U.K.), Salto Talaris (Tornier S.A.S., Saint Ismier, France) and Topez (Topez Orthopedics, Boulder, Co.) The newer generation of TAA designs features a nonconstrained polyethylene meniscus that articulates between the porous coated tibial and talar components. The concern for edge loading has been addressed in newer designs by reducing the superior polyethylene surface area, expanding the tibial component surface and even offering a convex tibial component. However, the last two designs mentioned above have a single tibial talar articulation. Accompanying these design improvements has been the development of more practical, effective, and safer instrumentation for implantation. These refinements in surgical precision, often with a long learning curve even in the most experienced surgeons' hands, have been essential to the success of TAA.

Complications with TAA remain relatively frequent when compared to TKA and THA, irrespective of surgeon's training method. Wound healing and malleolar fractures are the most common problems. Fortunately, an individual surgeon's experience increases the chances for favorable outcome. The combined improvements in implants, instrumentation, patient selection, and surgical technique make a greater than 90% ten-year implant survival realistic. Moreover, the incidence of malalignment, neurovascular injury, and material failure of TAA implants is diminishing. However, despite these improvements, impingement from bony proliferation, osteolysis/loosening, component subsidence, and failure to resolve pre-operative stiffness remain concerns. Further investigation will determine if TAA is cost-effective and whether or not conversion of ankle arthrodesis to arthroplasty is advisable. The future promises a full complement of revision and custom prostheses as well as using state-of-the-art adjuncts such as computer navigation to ensure ideal alignment

B2-1

IS THE BIRMINGHAM HIP RESURFACING ARTHROPLASTY CONSERVATIVE?

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In the United Kingdom, Hip Resurfacing is becoming increasingly popular in patients under the age of 65 with osteoarthritis of the hip. Concerns still exist as to whether this treatment is superior to a total hip replacement (THR), although the mid-term results of Hip Resurfacing do look promising. Recently doubt has been cast whether Resurfacing is really conservative in preservation of acetabular bone stock, as some series (1), have shown that the size of the acetabular components used is larger than in conventional hip replacements.

We have studied the results of this Unit in cases performed by the Senior Author and have already reported to this society at the San Francisco Convention that the functional results of Hip Resurfacing and CADCAM hip replacement are identical when measured with Oxford, WOMAC and Harris Hip Scores. We now have studied the acetabular component size used compared with conventional total hip replacements and have found that the size is identical or if anything, smaller for Birmingham Hip Resurfacings.

We believe that this is due to improved surgical technique allowing us to undersize the femoral head without risk of notching. This therefore enables us to use a much smaller acetabular component. To date we have had one neck fracture out of 650 which is much lower than other series. The other problem with downsizing the femoral head is that the head/neck ratio of the prosthetic construct is reduced, thereby theoretically reducing the range of movement of the hip, and we present the range of movement of our resurfacing hips compared with conventional hip replacements.

Overall we still believe that the advantages of the preservation of bone stock in the younger patients coupled with their equal functional outcome make it a good primary hip procedure, where revision will probably be needed.

1) J. M. Loughead, I. Starks, D. Chesney, J. N. S. Matthews, A. W. McCaskie, and J. P. Holland
Removal of acetabular bone in resurfacing arthroplasty of the hip: A COMPARISON WITH HYBRID TOTAL HIP ARTHROPLASTY
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B2-2

X-RAY ANALYSIS OF THE FEMORAL COMPONENT IN RESURFACING HIP ARTHROPLASTY - A COMPARISON OF TWO DIFFERENT RESURFACING SYSTEMS

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OBJECTIVE

The purpose of this study was to evaluate the stability of the resurfacing femoral component and to compare the radiographical changes of the two different resurfacing femoral components.

METHODS

We retrospectively reviewed 33 hips in 27 patients who underwent metal-on-metal hip resurfacing or hemiresurfacing with a minimum follow-up of 1 year.

Seventeen hips in 15 patients had a metal-on-metal hybrid resurfacing component (Birmingham hip resurfacing (BHR), Smith & Nephew Co) with the mean age at operation of 45 years and the average follow-up of 23 months. Sixteen hips in 12 patients had a hemiresurfacing component (Conserve, Wright Medical Co) with the mean age at operation of 51 years and the average follow-up of 30 months. All femoral components were cemented, but 9 of the metaphyseal stems (3 hips in BHR, 6 hips in Conserve) were cemented. Clinical and radiological follow-up were performed at three, six, and twelve months postoperatively and yearly thereafter. Implant migration, radiolucent lines around the metaphyseal stem, alignment change, neck thinning, and component loosening were checked.

RESULTS

Implant migration, alignment change, neck thinning, and component loosening could not be found in both components. Radiolucent lines around the metaphyseal stem were detected in 10 hips (59%) of BHR group, 9 hips in cementless stem and one hip in cemented stem. All radiolucent lines were within 1mm. Those Initial radiolucencies were found at the tip of the stem on 6 months after the operation, and then tended to gradually extend to the proximal area. However, there were no symptoms associated with those radiographical changes. On the other hand, no radiolucent line could be detected in Conserve group.

CONCLUSIONS

Resurfacing femoral components were stable at the short term follow-up. However, the prevalence of radiolucent lines around the metaphyseal stem was much higher in BHR than in Conserve. Stem stiffness and bearing surface may affect the bony response around the metaphyseal stem.

B2-3

EARLY EXPERIENCE WITH A RESURFACING: THE IMPORTANCE OF UNDERSTANDING THE LEARNING CURVE

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INTRODUCTION

Total hip replacement with conventional devices is extremely successful operation, but resurfacing is the intuitively logical solution for replacing an osteoarthritic hip, especially in the physiologically young and active. It is bone preserving and in the anatomically normal hip, reliably restores offset giving better restoration of mechanics. It also increases revision options, has a hard wearing bearing surface, and has a lower dislocation rate. However, currently it has only a short term follow up and concerns remain about long-term survival.

This study presents a single surgeon series of the Conserve Plus resurfacing arthroplasty (Wright Medical, USA) in a university teaching hospital.

METHODS

Since October 2003, this implant has been used by the authors. For the series reported surgeries were performed by the senior author, as well as fellows and senior residents under the lead author's supervision. There were 90 resurfacings (87 patients, 3 bilateral) performed. The cohort was divided into early experience (n=45) and established practise (n=45). It should be noted that there was a significant change of instrumentation between these two groups, the early surgeries were performed using an evolved set, consisting of a mixture of general and specialised instruments. The later surgeries were performed with a specifically designed integrated set of instruments.

RESULTS

The mean age of the patients was 57 years (range: 24-75). There were 6 revisions at a mean time of 23 weeks (3-83) since the time of index procedure. The commonest reason for revision was fracture (n=5); there was one revision for infection. The components were revised to a conventional THR with a large femoral head. There were 5 revisions in the first 45 cases, 1 in the second 45.

CONCLUSIONS

Resurfacing is a challenging procedure with a steep learning curve, but early results suggest that it may be particularly suitable for younger patients in whom conventional hip replacement may be less successful compared to an elderly population. Improved instrumentation and increasing experience has helped reduce the complication rate. Specific instruments are also easier to teach to fellows and residents. This study highlights the need for specialized training in hip resurfacing even for the experienced hip surgeon.

B2-4

REVISIONS IN HIP RESURFACING ARTHROPLASTY

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INTRODUCTION

Resurfacing Hip Arthroplasty (RHA) is being performed more frequently worldwide and clinical results have been encouraging. The majority of these patients are young and active. The advantages of hip resurfacing include less bone resection, reduced risk of dislocation because of the larger resurfacing head and easier conversion to a secondary procedure if failure occurs.

Because of the raising number of performed hip resurfacing arthroplasties, the number of hip resurfacing revisions will also increase. Known reasons for revisions are; acetabular and femoral component loosening, malpositioning, osteonecrosis of the femoral head and femoral neck fracture. The purpose of the present study was to determine the reasons for revision and the revision-options in patients who had resurfacing arthroplasty of the hip.

MATERIALS AND METHODS

One surgeon, who implanted 9 of the cases, performed 32 revisions of metal-on-metal surface arthroplasty devices. Twenty-one BHR (Smith & Nephew) devices, 5 Conserve+ (Wright Medical) devices, 4 ASR (DePuy) devices and 2 McMinn (Corin) devices were revised. Revisions were performed after an average of 24.2 months (range 1 to 76 months). The average age at revision was 49.7 (range 19 to 70 years). Twenty-nine surgeries were performed through a posterior approach and 3 surgeries were performed through a lateral approach.

RESULTS

The reasons for revision were malpositioning of the cup (56%), malpositioning of the head (6%), avascular necrosis (16%), fracture (16%), osteolysis of the head (13%), groin pain (6%) and ALVAL (9%).In 5 cases, which were revised for malpositioning of the cup only, it was possible to preserve a resurfacing arthroplasty. Only exchange the cup was necessary. In 10 patients the head was replaced for a stem with modular head, the cup not being replaced. In the other 17 cases the resurfacing arthroplasty was replaced by a uncemented or hybrid total hip ceramic-on-ceramic arthroplasty. In 22 patients the cup was changed. The average increase in cup-diameter was 2.1 mm. The last 19 revisions were the cup was changed, were performed through a posterior approach. The average increase in cup-diameter by this approach was 1.4 mm.

DISCUSSION AND CONCLUSIONS

Within this group of 32 resurfacing arthroplasties implanted by a number of surgeons with different levels of experience, acetabular malpositioning was the main cause of revision. While the exact incidence of this complication is unclear because most of the cases came from outside surgeons, malpositioning accounts for more than 50% of the failures in this series. The correct placement of both the acetabular and femoral components is critical for the optimal functioning of the bearings. The resurfacing procedure is more technically demanding than routine total hip replacement, particularly for surgeons new to the procedure. While acetabular malpositioning may seem to be a preventable cause of failure, this may only be achieved through better training, increased experience with the technique and a better understanding of the problem. There has been some concern that resurfacing may not be conservative of acetabular bone. This study shows that the average increase in cup-diameter after revision is only 1.4 mm.

B2-5

OUTCOMES OF LIMITED FEMORAL RESURFACING FOR OSTEONECROSIS OF THE FEMORAL HEAD

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INTRODUCTION

Limited femoral resurfacing is being used for treatment of late stage osteonecrosis before acetabular arthritic changes occur. Resurfacing may be used as a "time buying" procedure to prolong the need for total hip arthroplasty. The purpose of this study was to report our experience with limited femoral resurfacing for the treatment of osteonecrosis.

METHODS

The clinical and radiographic results of twenty-two limited femoral resurfacings were reviewed. This study included 14 men and 8 women whose mean age was 37 years (range, 19 to 54). Ten patients had failed previous core decompression. Patients with Harris Hip scores less than 80 points at last follow up or those who were converted to a total hip replacement were considered clinical failures.

RESULTS

Ten of twenty-two hips (45 percent) were clinically successful at a mean follow-up of 5.8 years (range, 24 to 82 months). Eleven hips were converted to total hip replacements for persistent groin pain at a mean of 4.8 years (range, 46 to 68 months). A twelfth hip is awaiting conversion. Two other hips have intermittent groin pain but have Harris Hip Scores greater than 80. Radiographically, there are three cases of decreased joint space when compared to immediate postoperative radiographs. However, these three patients remain asymptomatic.

DISCUSSION

Based on these results, limited femoral resurfacing should be considered an interim procedure for early collapsed hips. Although resurfacing may prolong the need for total hip arthroplasty, the surgeon and patient should be aware of the possibility of early revision.

B2-6

MODERN HIP RESURFACING IN THE TREATMENT OF FEMORAL HEAD OSTEONECROSIS

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A. INTRODUCTION

The results of total hip arthroplasty are generally poorer in patients with a primary diagnosis of ON as compared to those with primary osteoarthritis, although they are consistent and predictable in both diagnoses. However, as patients with ON typically present between the third and fifth decades, a conservative arthroplasty is desirable. Hemiresurfacing offers unpredictable results. Do the results of hip resurfacing match the consistent results of a total hip arthroplasty?

B. MATERIAL & METHODS

This is an ongoing review of 104 consecutive metal-on-metal resurfacings performed for Ficat stage III or IV AVN. Mean age at operation was 43.9 years. Etiology included trauma, steroids/ chemotherapy, alcohol abuse AVN secondary to Perthes/SUFE and idiopathic. Two devices were used a) McMinn Resurfacing Hip Arthroplasty, a hydroxyapatite coated smooth uncemented cup and a cemented femoral component and b) the Birmingham Hip Resurfacing (BHR), a hydroxyapatite on porous uncemented cup and a cemented femoral component.

C. RESULTS

At a mean follow-up of 6.3 years (range 2.7 to 12 years), there were eight failures (7.7% failure rate), five from further femoral head collapse, 2 infections and one aseptic loosening with osteolysis. The cumulative survival at 12 years is 89%. In one further patient the femoral component has tilted into varus from further collapse of the femoral head. He is asymptomatic but knows that he will need a revision if he develops symptoms.

D. DISCUSSION & CONCLUSIONS

One possible reason for poorer results of any type of treatment in ON as compared to the results in primary osteoarthritis is that the etiopathological factors that caused nontraumatic ON (steroids etc) have the potential to cause continued femoral head damage. This is seen by the 5% further collapse rate in the present series compared to 0.35% in the all diagnoses consecutive series of the senior author. The results in the present series are no different to those of THA in ON in many series. Being a conservative option, resurfacing is a desirable option especially in younger patients. Metal-metal resurfacing gives acceptable results in femoral head osteonecrosis.

B3-1

INCREASED BONE INGROWTH ON A BIOMIMETIC NANOCRYSTALLINE APATITE SURFACE

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Hydroxyapatite-coated femoral prosthesis implants have been successful clinically in primary total joint replacement. However, the success of hydroxyapatite as a coating on acetabular components and in revision joint replacement has been less striking, which is further compounded by concerns of delamination, third-body wear, and the eventual fate of the apatite coat. Typical plasma-sprayed hydroxyapatite coatings work well on non-porous substrates but do not coat the inner surfaces of open-porous substrates. Solution deposition can produce consistent bioceramic coats of precise thickness on porous surfaces. The resultant "biomimetic" surface more closely mimics the trabecular pattern and biochemistry at the bone interface. This report compares bone response to porous surfaces with biomimetic hydroxyapatite coatings.

Implants were manufactured as Ti6Al4V cylinders (5-mm diameter, 41-mm long) coated with c.p-Ti Porocoat® porous layer with a thickness of 500 (± 250 μm). Implants were divided into three groups based on surface treatments. The porous surfaces of Control group implants did not receive any treatment. The porous surfaces of PS group implants were plasma sprayed with hydroxyapatite. The hydroxyapatite coating consisted of crystalline hydroxyapatite, amorphous calcium phosphate, and β-tricalcium phosphate. The porous surfaces of BAp group implants were coated with a biomimetic apatite (BAp) coating using a low-temperature solution-based process that mimics bone mineralization. The implants were soaked in a physiologic solution to allow for the growth of nanocrystalline apatite substantially equivalent to bone mineral in structure and composition. BAp coating is a pure apatite coating of uniform structure and composition, with a thickness of approximately 15 μm on the outer beads. Because of the reduced thickness, the BAp coating does not block the pores or alter the porous structure.

Bilateral femurs in thirty-six rabbits were implanted with one of the above groups. Twelve rabbits each were euthanized at 2, 4 and 12 weeks. Scanning electron microscopy images of sections were taken through the implant at three levels: from diaphyseal to metaphyseal and analyzed by automated computerized histomorphometry. Bone ingrowth was quantified in the pores and measured as a percent of the available volume.

Bone ingrowth for the Control surface increased from 45% at 2 weeks to 47% at 12 weeks. Bone ingrowth for the PS surface increased from 51% at 2 weeks to 67% at 12 weeks. Bone ingrowth for the BAp surface increased from 45% at 2 weeks to 71% at 12 weeks. At both time points mean bone ingrowth for PS and BAp coated implants was significantly higher than for Control implants ($p<0.01$). By 12 weeks the PS hydroxyapatite coat began showing evidence of fragmentation and debris production on SEM. This was not evident in the BAp coat.

Bone ingrowth was higher in the hydroxyapatite-coated surfaces and continued to increase up to 12 weeks. This study supports the hypothesis that hydroxyapatite coating benefits osseointegration. A biomimetic coat of solution-deposited hydroxyapatite may not have the disadvantages of coating delamination and particle generation. Biomimetic apatite coatings may be attractive alternatives for noncemented total hip arthroplasty.

B3-2

PRELIMINARY STUDIES OF ATTACHMENT, SURVIVAL AND GROWTH OF BONE MARROW STROMAL CELLS ON NANOCRYSTALLINE ULTRA-HYDROPHILIC HARD ADHERENT CERAMIC COATINGS

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There is a great need to develop methods to regulate cellular growth in order to enhance or prevent cell proliferation as needed, to either improve health or prevent disease. The present studies were devised to evaluate the adhesion, survival and growth of cells on the surface of new **engineered nano-crystal films** of pure cubic zirconia (with a hardness of 16 GPa), titanium, tantalum, cerium oxides, as well as silver. In vivo, much of the proliferative activity in bone cell development is associated with mesenchymal precursors. However, in vitro, osteoblast cell lines often have characteristics resembling tumor cancer cells, including dysregulated cell proliferation. Consequently, their growth on surface coatings may not be typical of normal cells. Because of these concerns over the use of osteoblast cell lines, the current studies were performed using a cloned bone marrow stromal cell line from C57Bl mice termed OMA-AD cells. This is a spontaneously immortalized undifferentiated stromal cell population that resembles multipotential mesenchymal stromal cells (MMSC). OMA-AD cell line duplicates, in vitro, all of the characteristics of primary mesenchymal stem cells and is a valid experimental model to probe the impact of nanocrystalline hard ceramic coatings on the attachment, survival and growth of bone marrow stromal cells.

The **engineered nano-crystal films** with ultra-hydrophilic properties are produced by employing an ion beam assisted deposition (IBAD) technique. IBAD combines physical vapor deposition with concurrent ion beam bombardment (ionic hammer), in a high vacuum environment, to produce films (with 7 to 70 nm grain size) with superior properties. These films are "stitched" to the orthopaedic artificial implant materials with characteristics that affect the wettability and mechanical properties of the coating.

Because of the opacity of substrates of our preliminary samples, the OMA-AD cells on these surfaces had to be viewed in incident light. Morphologically, there were different frequencies of cells attached to the different surfaces. For example, preparations of zirconium oxide had the highest frequency and silver the lowest frequency of cells. Also morphologically, the cells attached to some surfaces, for example tantalum oxide, showed much greater spreading with occasional large "blanket" cells. Based on cell counts, silver supported the lowest growth (about $1x10^3$ cells/cm^2), tantalum and titanium oxide and some preparations of zirconium oxide were intermediate ($3\text{-}6x10^3$ cells/cm^2, but note, some of these cells were very large, and one surface nanostructure of cubic zirconium oxide supported approximately $8x10^3$ cells/cm^2). These data demonstrate that both **materials and their nanoscale properties** influence attachment, survival and growth of MMSC. Although the biophysics of these differences is currently uncertain, as is the impact on the differentiation of OMA-AD cells to bone forming cells, further experiments are in progress to better understand this interaction between cells and nano-structured coatings.

B3-3

THE EFFICACY OF ORTHOBOND COATINGS IN THE BIOLOGICAL FIXATION OF METALLIC IMPLANTS

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Biological fixation of metallic implants is a complex phenomenon, involving the processes of osteoconduction and osteoinduction. Porous ingrowth options in current use require both mechanical and chemical modifications of the metallic surface for optimal success. Mechanical alteration of metallic surfaces is now a straight forward process, but chemical treatments, such as hydroxyapatite (HA) coatings, are more complex and expensive.

The purpose of this study was to evaluate the efficacy of using a porous metallic surface treated with a new chemical process (ORTHOBOND) that renders the surface osteinductive. This relatively easy and inexpensive process is composed of a single layer of phosphonate molecules covalently bonded to the metal oxide surface.

Sixty skeletally mature New Zealand white male rabbits had beaded titanium cylinders (5mm diam, 25mm long) inserted retrograde bilaterally into their distal femora. The cylinders were treated with one of three coatings: 1) Orthobond alone (ORT), 2) Orthobond and an RGD peptide (ORGD), or 3) HA alone. Fifteen rabbits were sacrificed at each of 4 time intervals: 2, 4, 8, and 16 weeks with 10 specimens of each coating randomly assigned to femora for each time point. All femora were harvested and subjected to either mechanical or histological analysis.

Mechanical pullout tests were performed using a customized jig to assure uniaxial alignment under load control. Histological analysis was performed to obtain a quantitative and qualitative assessment of bony ingrowth.

Statistical analysis was performed on the failure loads using ANOVA on Ranks followed by a Mann-Whitney post-hoc test. Differences were considered significant with $p<0.05$.

Both Orthobond groups had significantly higher failure loads when compared to HA at 4 weeks ($p<0.01$) suggesting a more rapid osteinductive process. No significant differences were found between groups at later intervals, although the Orthobond groups remained stronger at 16 weeks.

Using double tetracycline fluorescent labels, the rate of mineralization around all three groups was similar. In the metaphyseal region, a loss of trabecular density occurred in the medial-lateral direction surrounding the rods of all femora in all three groups.

The trabecular characteristics in the anteroposterior direction were different between the three groups. Cortical bone bridging was note in the metaphyseal region between the rod and the endosteal cortex in the Orthobond treated rods; in the HA group, trabecular bone bridging occurred in this region.

Our biomechanical and histological analyses of this novel coating are very encouraging. Where early implant fixation is important, the Orthobond treatment provides a simple, cost-effective means for enhancing the speed of bony integration of implants. With the Orthobond treatment, with or without RGD, the failure load of implants doubled in half of the time as compared to hydroxyapatite.

B4-1

IN VIVO 3D DYNAMIC DETERMINATION OF NORMAL, DEGENERATIVE AND FUSED CERVICAL SPINES

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Understanding *in vivo* dynamic characteristics of normal, pathologic, and post-operation cervical spines is important to predict and evaluate the success of present surgical technologies and provides a basis for surgeons and biomedical engineers to design the next generation prostheses.

The objectives of this research was to determine the *in vivo* dynamic differences between the normal, degenerative and fused cervical spines and compare the results to see if the motion patterns and bearing surface forces in the fused cervical spines are statistically different to cause degeneration in adjacent levels. Three normal, three degenerative and three fused patients performed full flexion/extension, lateral bending and axial rotation motions under fluoroscopic surveillance. CT images were used to create 3D CAD models of each level of the entire cervical spine; MRI images were utilized to determine muscular and ligamental attachments and orientation directions. Three-dimensional *in vivo* kinematics was determined for each of these three different motions (flexion/extension, axial rotation, and lateral bending) using SAAM, which is fluoroscopic analysis software package created to recover 3D motion from 2D fluoroscopic sequential images.

According to the different functions of major muscles and ligaments used to perform these three motion patterns, an inverse dynamic model of the entire cervical spine, including ligamental and muscular forces, was derived using Kane's dynamics and a reduction modeling technique. The model is programmed by automatically switching between six separate sub-routine models linked with main algorithm. The biomechanical anatomic structures of the cervical spine, including facets, intervertebral discs, and major ligamental and muscular functions were considered in the model. Wrapping of muscles, such as the sternocleidomastoid, around the vertebral bodies implemented by altering the position vectors at wrapping points. Bearing surface forces were determined for each subject and compared to subject specific data and to other groups. Subjects having a fused cervical spine experienced statistically greater forces at the adjacent bodies. A sensitivity analysis was performed to determine which parameters lead to altered mechanics. An error analysis was also conducted using a cadaver.

The previous results clearly demonstrate that the fused patient has increased motions and forces at both adjacent levels when compared to the normal and degenerative patients, within comparable neck motion ranges. These results may lead to a better understanding of 3D *in vivo* mechanics of different cervical spine conditions and may allow for better treatment of cervical spine disorders.

B5-1

TRABECULAR METAL TANTALUM CUPS IN THR

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INTRODUCTION

Osteointegration has raised as the key point in the development of a stable biological fixation in prosthetic surgery. Traditional biomaterials have different structural and ultra structural limits which reduce their applications.

Recently pure tantalum has been proposed in orthopaedic surgery. Its chemical and physical properties have been widely studied in the past. From pure tantalum is obtained a spongy structure (Trabecular Metal Technology: TMT) that shows a full thickness porosity which is 2-3 times higher compared to other surfaces available for bone ingrowth with a three-dimensional porous arrangement in rough trabeculae. Pores (average diameter of 650 μm) are fully interconnected and represent 75-80% of the whole volume. TMT acetabular components have an elliptical shape and have an irregular external surface which both allow an optimal mechanical fit.

MATERIAL AND METHODS

From 1999 to 2006 a monoblock porous tantalum acetabular cup was implanted in 316 patients; we reviewed 212 hips with a 3-7 years follow-up. There were 98 men and 114 women, with a average age of 65 years. They all underwent to primary or revision total hip arthroplasty or to acetabular component revision alone. The preoperative diagnosis was: osteoarthrosis (133 cases), rheumatoid arthritis (21 cases), fracture neck of femur (16 cases), loosening (29 cases), osteonecrosis (13 cases). In all patients a monoblock porous tantalum acetabular component (formerly Hedrocel, Stratec Medical, more recently TMT, Zimmer) with polyethylene directly compression molded into cup was implanted, with or without peripheral holes for screws. In all primary procedures the same stem (Synergy, Smith & Nephew) was used.

All patients were evaluated with a clinical examination (Harris Hip Score: HHS) and with standard radiographs preoperatively and 1, 3, 6 months and yearly postoperatively.

RESULTS

The HHS score improved from 42 preoperatively to 94 after one year; at 7 years follow-up it was 95. The subjective outcome was widely satisfying, with the majority of patients experimenting good functional recovery and return to daily activities. Osteointegration of the acetabular component was present in all X-rays controls at one year after surgery. All preoperative evidence of bone loss (geodes, bone defects in revisions and in displasia) were not radiographically evident after 3-6 months postoperatively as the host bone quickly filled these gaps. We did not observe osteolysis nor progressive radiolucent lines at the latest follow-up. None of the cups was revised.

DISCUSSION

Despite our short follow-up and small series some conclusion can be taken. Both clinical and radiographic results are the same or even superior to those of coated implants. Our experience confirms that trabecular metal tantalum cups can avoid the formation of bone-implant interface membrane and consequently can avoid implant loosening. The most important advantages of TMT monobloc cups are: no potential for polyethylene backside wear, prevention of loosening and osteolysis, increased early fixation via friction, improved late biological stability, maximum bone-implant contact. High biocompatibility of porous tantalum and its elastic modulus very close to bone influence positively earlier and wider osteointegration of the implant. Longer follow-up with larger series are needed to confirm the positive preliminary results.

B5-2

NO PERI-PROSTHETIC RADIOLUCENCY AT 10 YEARS AROUND A PURE TITANIUM PRESS-FIT CUP: IMPORTANCE OF EQUATORIAL FINS FOR INITIAL MECHANICAL STABILITY

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Press-fit cups have given excellent clinico-radiographical results. This is a retrospective clinico-radiographical study about the long term performance of pure Titanium cementless modular press-fit cups (Fitek^{TM}) having, on the outer surface, an oriented multilayer titanium mesh (Sulmesh^{TM}) with 65% porosity (average pore size=400-640 micron). The cup was implanted after underreaming the acetabulum by 2 mm. In the cup's equatorial area there are two "fins" originary designed to improve rotational stability but actually representing two excellent primary mechanical stabilizers.

We have evaluated the first 100 consecutive cups implanted in 92 patients with an average FU of 9,7 years (range 9-11 years). All operations have ben performed by the two Senior Authors (PGM and RB). Regarding etiology, we had 43 Primary Arthritis, 37 Dysplastic Arthritis, 12 Osteonecrosis and 8 Post-traumatic Arthritis. Results were evaluated with the Harris score. Radiographic evaluation was performed using AP and lateral x-rays pre-op.post-op and at the last follow-up.

We had 86 Excellent, 10 Good, 2 Fair and 2 Poor. The 2 Poor results were 2 aseptic loosenings of the stem

The Mann-Whitney nonparametric U test and the Kruskal-Wallis test showed that the survival rate of the 100 analyzed cups, after a mean follow-up of 9.7 years, was 100% (end point: revision for any cause)

Etiology was not statistically correlated with post-op score.

Nevertheless, dysplastic patients showed inferior results compared to arthritic patients in different parameters, as pain, limp, Range Of Motion ($p < 0.05$), putting socks and shoes ($p < 0.05$).

Our cups were intentionally implanted and radiographically appear in a fairly horizontal position (36.5° on average).

In 6 cases we could calculate an eccentricity of the metal heads proving bidimensional linear wear of the liner (average 0.265 mm / year). At the last follow-up we had 3 femoral osteolysis, while in the acetabular side radiolucent lines were present in 14 % of the cases, never progressive.

In no case we found a change of position of the cup, and in this series no revision was necessary.

Fitek^{TM} cementless cups gave excellent results at 10 years with complete stability and osteo-integration. Excellent primary mechanical stability was given by the rough surface (Sulmesh^{TM}) and by the two "fins" in the equatorial area.

Therapeutic study, Level of evidence IV

B5-3

TREATMENT OF PELVIC OSTEOLYSIS IN A STABLE CEMENTLESS CUP WITH LINER EXCHANGE

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PURPOSE

To analyze the results of treatment of pelvic osteolysis with retention of acetabular metal shell and polyethylene liner exchange. We retrospectively evaluated twenty seven hips which underwent revision surgery for pelvic osteolysis.

MATERIALS AND METHODS

We performed liner exchange for massive osteolysis around stable HG acetabular cups with severe polyethylene wear in twenty-seven hips between June 1996 and May 2004. In 25 hips, we performed curettage of granulomatous tissue and tightly packed morselised cancellous allograft through the screw holes or the peripheral rim for osteolytic lesions. Two hips underwent liner exchange only. The mean follow-up period was 3.8 years (2.4-9.3 years) and the mean duration before component exchange since primary total hip arthroplasty was 8.2 years (5.6-12.4 years).

RESULTS

During the follow-up period, all the hips were functioning well, and none have required subsequent re-surgery for any reason. Dislocation after the revision surgery occurred in one hip which was successfully treated with an abduction brace. None of the hips showed progression of the pre-existing osteolytic lesion or development of new osteolytic lesions. At final follow-up, none of the acetabular components showed any evidence of loosening.

CONCLUSION

Our results showed that isolated liner exchange and debridement of the granulomatous tissue with or without bone grafting is a reasonable alternative solution to revision of the cup for massive osteolysis around well fixed cementless acetabular cups in selected patients. Retention of the well fixed cementless acetabular cup ensures less intra-operative and post-operative morbidity associated with a cup revision. However, to determine the longevity of the retained cementless acetabular cups, further long-term study is necessary.

B5-4

SHORT TERM RESULTS OF CUSTOM TRIFLANGE ACTEABULAR COMPONENT FOR MASSIVE PERIACETABULAR BONE LOSS IN REVISION HIP ARTHROPLASTY

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INTRODUCTION

Managing severe periacetabular bone loss during revision hip arthroplasty is a challenging task. Multiple treatment options have been described. A custom triflanged acetabular component (CTAC) is a more recent treatment option.

METHOD

A retrospective review was done of 19 hips (19 patients) with massive periacetabular bone loss (Paprosky Type 3A/3B) treated with a CTAC. Mean patient age at time of surgery was 58 years (range 42-79 years). Harris Hip scores and WOMAC scores were collected for all patients, as well as radiographic data. Data regarding the revisions and re-operations and post operative complications were obtained from the clinical records, along withv patient satisfaction.

RESULTS

At average follow-up of 31 months (range 16-59 months) mean Harris Hip Score had improved from 38 preoperatively to 63 at latest follow-up. Mean WOMAC score also improved from 43 preoperatively to 26 at latest follow-up. Sixty-five percent of cases were considered a successful result. Forty-three percent stated ambulatory status was improved, 21% stated no change, and 36% stated ambulatory status at latest follow-up was worse than preoperative status. Three patients (16%) had significant postoperative complications. Two (10.5%) CTAC components were removed due to failure.

CONCLUSIONS

The use of CTAC for massive periacetabular bone loss in revision hip arthroplasty has less favorable results in this study than in other reports in the literature. Use of CTAC is still a viable option in cases of severe periacetabular bone loss but surgeon and patient expectations should be realistic regarding outcome.

B5-5

DYSPLASIA BIRMINGHAM HIP RESURFACING ARTHROPLASTY FOR DEFICIENT ACETABULAE

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A. INTRODUCTION

The purpose of the present study is to study the clinical, radiological and functional outcome of the Birmingham Hip Resurfacing Dysplasia system in patients with deficient acetabulae.

B. MATERIAL & METHODS

One hundred and ten consecutive dysplasia BHRs performed for the treatment of severely arthritic hips with Crowe grade II and III dysplasia between 1997 and 2000 were reviewed at a minimum five year follow-up. Of the110 hips (103 patients, 57M and 46F), 79 were old CDH or DDH, 27 severe destructive primary or secondary arthritis with wandering acetabulae and four were old fracture dislocations of the hip. Mean age at operation was 47.2 years (range 21 to 68 years). Autograft obtained from the socket reamers was used to fill in the deficiency in the dysplastic acetabulum.

C. RESULTS

There were two failures (1.8%) out of the 113 hips at a mean follow-up of 6.6 years (range 5 to 8.3 years). One hip failed with a femoral neck fracture nine days after the operation and another failed due to deep infection at 3.3 years. One patient died after 5.2 years after the operation due to an unrelated cause. Excellent osseointegration of the bone graft was found in all patients. None of the components failed from aseptic loosening.

D. DISCUSSION & CONCLUSIONS

The dysplasia cup has lugs to fix two neutralization screws. These screws obtain good purchase in the more proximal healthy bone of the ilium and offer effective early fixation to the cup. The superolateral deficiency in the bony socket is then filled with impacted bone graft. This device offers a good conservative arthroplasty option for these severely deficient hips.

B5-6

EFFICACY OF USING TIBIAL OFFSET STEM IN REVISION KNEE ARTHROPLASTY

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INTRODUCTION

In revision knee arthroplasty, it is difficult to set implant in a suitable position by exact alignment. In tibial side, the center of proximal tibial canal often deviates medially from the center of tibial tray, so medial offset stems are necessary for such cases to set the tibial components in a good position. In this study, we investigated how the proximal tibial canal deviates from the center of tibial tray and the relationship between offset stem and mechanical alignment of the lower leg.

MATERIAL & METHODS

Seventy-four revision TKAs were performed between January 2001 and December 2003 by one surgeon and 29 knees were investigated retrospectively with frontal view of full length leg films after the surgery. One short stem (stubby stem) and 1 tibial component without stem were used, and 140mm canal filling stems were used in 27 remaining knees. Among the 27 knees, medial offset stems were used in 24 knees (89%) and lateral offset stem was used in 1 knee. Straight stems were used in 2 knees. The line passing through the center of osteotomized tibial plane and the center of talus was defined as tibial mechanical axis (TMA), and the distance between TMA and the center of proximal tibial canal in a stem tip level was measured, which was defined as Deviation of Tibial Canal (DTC). The alignment of the tibial component and the angle between TMA and tibial anatomical axis (TAA) in a distal stem level (2cm distal level from stem tip to 5cm proximal level from stem tip) were also measured to assess the efficacy of using offset stem.

RESULTS

The proximal tibial canal deviated medially from the center of osteotomized tibial plane in 23 of 29 knees (79%) and DTC was -3.4±3.4 (Mean±S.D). The alignment of tibial component was 0.04±1.7 degree (Mean±S.D), which means almost tibial components were set in neutral position. The angle between TMA and TAA was 0.3±0.96 degree (Mean±S.D), which means TMA was almost parallel to TAA.

DISCUSSION & CONCLUSIONS

It is important to understand the anatomy of the proximal tibia to set the tibial component in a suitable position. The radiographic measurements revealed that the proximal tibial canal often deviated medially from the center of osteotomized tibial plane in revision surgery and that TMA was almost parallel to TAA and almost tibial components were set in neutral position. Therefore it is considered that medial offset stem is effective to set the tibial component in a good position in most revision cases and exact tibial component alignment will be obtained by inserting the canal filling stem along the proximal tibial canal.

B5-7

TIBIAL STEM DESIGN IN REVISION ARTHROPLASTY: CONCERNS RELATED TO TIBIAL FIXATION

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Revision TKA can be a complex undertaking that must result in restoration of alignment and stability to the knee joint if success is to be achieved. The use of modular components has increased the intraoperative flexibility of the surgeon and allows the surgeon to independently address each of the issues necessary to achieve a successful reconstruction. The Scorpio Revision Total Knee Arthroplasty (TKA) System offers a number of features with the potential to improve the predictability of the final outcome. These features include modular stems with the ability to predictably offset components for both the femur and tibia, a wide range of tibial inserts to address the range of stability needs of the reconstructed knee, augmentation blocks for the femur and tibia to allow restoration of the joint line with loading of the bone, and design features that allow application of the single axis of rotation concept in revision TKA. The senior author has over 15 years experience with the use of modular components in revision total knee arthroplasty (TKA). He began using the modular Scorpio Revision TKA System in July 2000. This retrospective study represents five years of experience using that device.

A total of 67 revision TKAs in 63 patients were performed by a single surgeon using the Scorpio Revision TKA System from July 2000 through June 2005. Reasons for revision included instability (56), malalignment (10), wear (28), loosening (23), arthrofibrosis (6), infection (5), and other (10), with multiple reasons for revision in (50) knees.

At the most recent follow-up (average: 32 months, range: 16-69 months) 2 patients have died (non-related causes) and 10 have needed additional surgical intervention: 2 for instability, 2 for loosening (1 revised elsewhere), 2 for shin pain (1 stress fracture of distal tibia) requiring cementation of the stem, 2 for infection and 2 required synovectomy with debridement for pain. 10/28 (35.7%) patients with uncemented stems complained of shin pain, 2 severe enough to require re-operation as mentioned above and 3 severe enough to require conservative treatment. 6/39 (15.4%) patients with cemented stems also complained of shin pain, however none required re-operation or conservative treatment. Average knee scores improved post-operatively.

The Scorpio Revision TKA System of implants and instrumentation has provided substantial intraoperative flexibility addressing the wide range of problems encountered during revision TKA. However, the use of diaphyseal engaging uncemented tibial stems has been particularly disappointing, and represents an issue of implant and instrumentation usage that needs to be addressed. The author suggests that only metaphyseal cemented stems be used for tibial fixation with this system

B6-1

LEARNING CURVE OF A NAVIGATION SYSTEM FOR TOTAL KNEE REPLACEMENT. A MULTICENTRIC STUDY.

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INTRODUCTION

Navigation systems have proved to improve the accuracy of the bone resection during total knee replacement (TKR). Most papers have been published by centers highly experienced in navigation. It is then questionable if less experienced centers might get the same accuracy. We performed a prospective, multicenter study to compare the accuracy of implantation of a TKR in experienced and less experienced centers.

MATERIAL

All centers implanted a high volume of TKR (more than 150 cases per year) prior to this study. A new implant type (E-motion ^{TM}, Aesculap, FRG), a mobile-bearing, PCL preserving TKR) was introduced in all centers at the beginning of the study, which collected the results of the first consecutive cases in all centers, so that the experience of each center with the implant system cannot represent a bias. All centers used the same non image based navigation system (OrthoPilot ^{TM}, Aesculap, FRG): 4 had already a significant experience with it (group A – 182 cases), 9 centers were considered as beginners with less than 10 cases performed prior to the study (group B – 221 cases).

METHODS

Accuracy of implantation was measured on post-operative antero-posterior and lateral long leg X-rays. The TKR was implanted with the following goals: mechanical femoro-tibial angle from 177 to 183 degrees, coronal orientation of the femoral component in comparison to the mechanical femoral axis from 88 to 92 degrees, sagittal orientation of the femoral component in comparison to the anterior femoral cortex from 85 to 95 degrees, coronal orientation of the tibial component in comparison to the mechanical tibial axis from 87 to 93 degrees, sagittal orientation of the tibial component in comparison to the posterior tibial cortex from 87 to 93 degrees. The number of items in the desired range was summarized by each patient, giving an accuracy note between 0 and 5. The mean accuracy note was compared in the two groups by an ANOVA test at a 0.05 level of significance. Each individual item was compared between the two groups by mean comparison (ANOVA test, 0.05 level of significance) and by comparing the number of outliers in both groups (Chi² test, 0.05 level of significance). Power of the study was 0.80.

RESULTS

Mean accuracy note was 4.0 in group A and 4.1 in group B ($p>0.05$). The mean femoro-tibial angle was 0.6° in group A and 0.9° in group B ($p>0.05$). It was considered in the expected range by 164 patients in group A (90%) and 194 patients in group B (88%) ($p>0.05$). There was no difference between both groups for all X-ray criteria. Mean operative time was 10 minutes longer in group B ($p=0.01$), but this difference disappeared in the 10 last cases.

DISCUSSION

The used navigation system allowed a very accurate implantation of a TKR in both experienced and less experienced centers. The only observed difference was the operative time during the 20 first cases. The learning curve of the used navigation system can be regarded as very short in high volume TKR centers.

B6-2

ROTATIONAL ALIGNMENT OF FEMORAL COMPONENT IN TKA

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INTRODUCTION

Total knee arthroplasty is a well standardized procedure. New materials and instrumentations have improved surgical precision and postoperative results. The problems of bone resections and component positioning are still a source of discussion. From the beginning two major philosophies has been introduced: the "mechanical theory" proposed by Insall and "the anatomical theory" proposed by Hungerford. According to these theories several techniques were developed to achieve the correct femoral component rotation. The posterior condylar plane, the fixed 3° of external rotation, the epicondylar axis and the anterior-posterior axis are the most common references for posterior femoral resection. Some debate still exists about the effective precision and reproducibility of these methods.

In the attempt to give an answer to these concerns, we performed a CT scan study to check the real precision of the two most common techniques: the epicondylar axis and the fixed 3° of external rotation.

MATERIAL AND METHODS

A group of 20 patients candidate for total knee replacement were treated with the same posterior stabilized implant (Zimmer Nexgen LPS). The population was randomly divided into two groups at the time of surgery. In the first group femoral rotation was established for each patient with the guide of a set of jigs. These take the epicondylar axis as reference allowing independent resections. In the second group, a single jig for dependent cuts (5-in-one) was used. Posterior femoral rotation was performed in all these patients with fixed 3° of external rotation from the posterior condyles plane. The patella was not resurfaced in all patients. Preoperative and postoperative protocol was the same in all cases.

In the first group a postoperative CT scan was performed to asses the real external rotation obtained. The angle between the surgical epycondilar axis and the plane of posterior resection was measured assuming 0° as the expected value. In the second group, due to the wide anatomical variations, both a preoperative and postoperative CT scans were performed. The angle between posterior condylar plane and epicondylar axis was preoperatively measured. This value should ideally be increased of 3° postoperatively.

RESULTS

In the first group the average value was 0.6° of external rotation referenced to the epicondylar axis. There was a wide data dispersion (minimum -4.2°and maximum 3.9). Negative values are given when the plane of posterior condyles is internally rotated referenced to the epicondylar axis. In the second group the average value obtained was 3.4°. There was a high dispersion in this group too (minimum 0° and maximum 7.9°). Lateral release was necessary in 4 cases (2 in the first group and 2 in the second). Average external rotation of these 4 patients was 0,9° while the average external rotation of the whole population was 0,8°.

DISCUSSION

These preliminary results show good average precision in determining the femoral component rotation with both techniques; however a wide data dispersion was observed. In the first group this is in accordance to the literature data and is the consequence of the technique itself (difficulty in palpating the epicondyles intraoperatively). Concerning the second group the wide data dispersion is the consequence of surgical and measurement errors.

B6-3

NAVIGATED UNIVERSAL KNEE INSTRUMENTATION: A FAST AND PRECISE METHOD FOR MAKING ALL FEMORAL CUTS IN TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

A key issue in Total Knee Arthroplasty (TKA) is to correctly align the cutting guides on the bone in order to insure perfect placement of the implant with respect to the patient anatomy. Recently, 8in1 cutting guides have been introduced, which permit the surgeon to perform all five planar cuts plus the three notch cuts using only one guide template and insure high congruency of the 8 cuts and consequently good fit of the prosthesis on the bone.

Such templates typically cover most of the exposed femoral bone surface, however, it remains challenging to adjust all 6 degrees of freedom simultaneously. Our goal was to develop a positioning system for a complete cutting guide that has the advantages of accuracy, speed, and simplicity. We propose a solution using variable constraints that can be adjusted in surgery to conform to the shape of the patient's bone.

MATERIAL AND METHODS

We integrated an array of "adjustable constraints" into the new MIS UKI® (Universal Knee Instrument, Precimed, USA), a versatile 8-in-1 femoral cutting guide, by machining a number of threaded holes directly through the template. The protocol has been implemented on the Surgetics® Station platform (PRAXIM-medivision, France), which uses image-free Bone Morphing® technology to intra-operatively reconstruct the bone surface geometry. Two anterior cannulated screws adjust primarily axial rotation and flexion, while two distal ones control varus/valgus and proximal/distal positioning. Antero-posterior positioning is fixed by a mechanical constraint and medio-lateral positioning is done free-hand using centrelines rendered on the navigation interface. In total, this configuration has 1 fixed and 4 variable constraints.

The surgeon can virtually plan the implant size and position based on the mechanical axis, knee balancing, and the 3D BoneMorphing surface. The system then automatically computes the required screw adjustments. The surgeon or assistant can pre-set each screw following the indications on the screen and using a special graduated screwdriver such that when the template is positioned on the bone it already corresponds to the desired position. The navigation interface assists the "fine-tuning" step by displaying in real time which screw to turn in which direction, and by how many turns, to bring the guide to the planned position. Finally, small pins inserted through the cannulated screws allow the guide to be stabilized to the bone while fixing the device.

RESULTS AND DISCUSSION

To test the adjustable constraint configuration, we first tried the system on synthetic bones with several subjects before carrying out tests on cadavers. In our initial prototype, we incorporated different screw positions to determine empirically which combination of positions worked best for stability and ergonomics. The synthetic bone and cadaver experiments showed that pre-adjusting alone positioned the UKI within 1-2° and 1-2mm from the desired position, though the final position could always ±1°/mm be brought within during the fine tuning step.

In conclusion, we demonstrate that it is possible to precisely adjust the position of an 8in1 cutting block without any primary fixation on the bone, considerably simplifying the instrumentation and making the global navigation process very fast.

B6-4

DOCUMENTATION AND POST-OPERATIVE ANALYSIS OF SURGICAL SKILLS THROUGH REAL-TIME MOTION RECORDING OF NAVIGATED ARTHROPLASTY INSTRUMENTS

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There are no formal procedures to document or correlate the motion of surgical instruments during arthroplasty with the critical paths of surgery and with surgical skills. This study presents a novel method to record the motion of surgical instrumentation during arthroplasty using navigation for documentation, surgical skills assessment, and safety analysis. Whilst video recording can be used, it presents massive amounts of "incoherent" data which cannot be computationally processed without cumbersome object tagging and image analysis. Our particular need for such data emerged when optimizing the orientation/ motion of the surgeon's cutting tools relative to the patient's bone in the Nebraska Orthopaedic Minimally Invasive Surgery System (NoMiss) for Total Knee Replacement using navigated freehand bone cutting. In previous studies we presented this approach in which the surgeon is guided during cutting by real-time computer graphical feedback of realistic 3D models with directly navigated cutting tools and bones. With these objects being tracked, there was abundant time-synchronous raw data for recording at high temporal resolution.

Special software routines were developed to record the positions/motions of instruments and bones obtained intraoperatively from the navigation system. The data (recorded in quaternions and/or orthogonal coordinates) was progressively buffered in synchrony with the rendered 3D scene of surgery and dumped into a storage device (hard drive). The time interval between samples was user-selectable but naturally could not exceed the sampling rate of the navigation system. Although this sampling interval remained constant, a time stamp was recorded for each entry to ensure accuracy across different navigation devices (optical or magnetic), hardware and graphical devices of the CAOS system.

The above routines were successfully incorporated into the NoMiss software. Storage of a detailed history of the bone reshaping process for the distal femur in TKR could be done up to several hours if needed without compromising the system's vital functions of real-time rendering, tracking or simulation of the surgical scene. Several distal femoral TKR cuts (on synthetic bones) were test-recorded to prove the robustness of the routines. The data was successfully processed and exported to standard analysis packages (eg. MS Excel). The same stored data allowed playback with custom software routines within NoMiss to re-render at any time realistic dynamic 3D scenes of the complete bone cutting/refining process comparable in quality to video. The size of the data stored was only about 2 MB per hour of surgery, which represented not only digital, but a vectorial (therefore coherent) record. Furthermore, the 3D scene could be viewed during playback from any perspective angle, pan, zoom, and with any attribute (e.g. color, transparency, etc.) of any of the objects.

Beyond documentation and surgical skills analysis, such data can be used for optimization and training of surgery, and as a teaching input for robotics in orthopaedics. Future steps include better data compression, protocols for automatic analysis of the data and interpretation, and experimental trials on a wide variety of surgeons to verify the sensitivity of the technique to subtle variations in human surgical skills.

B6-5

A COMPARISON STUDY: BILATERAL TOTAL KNEE ARTHROPLASTY WITH AND WITHOUT SURGICAL NAVIGATION

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A retrospective study was performed to validate the use of surgical navigation for bilateral total knee arthroplasty (TKA). Some surgeons have warned against the use of bilateral TKA, fearing it can result in excessive intramedullary (IM) fat burden to the system, influencing pulmonary and hemodynamic stability intraoperatively. The goal of the study was to evaluate the difference in accuracy and safety for patients undergoing bilateral TKA with and without surgical navigation since surgical navigation involves a technique that does not invade the medullary canals of the femur or tibia.

Two consecutive groups of 28 patients who had bilateral TKAs performed by the same surgeon were selected. The groups were comparable with respect to gender, height, weight, age and diagnosis. The standard instrumentation was used to achieve appropriate alignment and stability for one group, and the Stryker Knee Navigation System (Kalamazoo, MI) was used for the other group.

Knee Society scores were used for clinical evaluation, while component placement and alignment was determined using the Knee Society Radiological Evaluation. Perioperative and early postoperative clinical activity was assessed, including blood usage, tourniquet and anesthesia times, intra-operative anesthetic stability, length of hospital stay, and postoperative complications. For this study, intra-operative anesthetic stability was defined as the absence of notable changes in SaO_2, BP or HR since those parameters have been associated with the incidence of fat embolization.

At the one year follow up interval, the average pain score and knee score for the two groups did not differ significantly, but the average function score differed in favour of the standard instrumentation group. Intra and postoperative medical complications were comparable in both groups, and blood usage did not differ significantly. Anesthetic instability was identified in one patient in the standard instrumentation group vs. none in the navigation group, but this was not statistically significant. Alignment and component placement were notably better in the navigation group.

The retrospective nature of this study did not allow us to specifically look at the issue of IM fat displacement, as that would require a prospective and somewhat invasive approach to determine. However, we were able to evaluate parameters associated with the incidence of fat embolization and results suggest that surgical navigation is a suitable approach for patients undergoing bilateral TKA. Safety was not compromised and accuracy was improved using navigation for component placement and alignment in bilateral TKA.

B6-6

Navigation versus Manual TKA: The Impact of Computer Assisted Surgery on Training in TKA Surgery

S David Stulberg, Mark Yaffe, Samuel Koo

Introduction: The use of computer-assisted surgery (CAS) by Orthopaedists experienced in the performance of total knee arthroplasty (TKA) results in better overall limb and implant alignment and fewer outliers.[1-6,8,9] Each of these studies demonstrated superior limb and implant alignment results with CAS as compared to manual TKA. However, no studies have established whether these improvements in alignment accuracy are associated with superior clinical and patient-perceived functional results. In addition, no studies have examined the potential training effects that occur when experienced surgeons use CAS TKA techniques. CAS may offer experienced TKA surgeons the potential to improve their TKA technique and improve their ability to perform TKA manually through intraoperative training effects provided by working with CAS. For example, in severely obese patients, proper limb alignment may not be readily apparent on initial visualization or with a standard mechanical alignment system. However, through the use of a navigation system, it is possible to obtain real-time alignment measurements during the performance of the surgical procedure. The intraoperative feedback provided by the navigation system offers the surgeon the ability to adjust his or her perception and assessment of proper limb and implant alignment. This training effect may result in more accurate TKA performed using manual instrumentation. There were two goals of this study. The first goal was to compare the clinical, patient-perceived functional and radiographic results of manually performed TKA with the results obtained using CAS techniques and the second goal was to assess the impact of extensive experience with CAS on the manual technique of an experienced TKA surgeon.

Methods: Seventy-eight consecutive TKA were performed by a single surgeon with extensive prior experience in both CAS and manual TKA. Of the seventy-eight TKA, forty were performed with manual instruments and thirty-eight with CAS. The groups were identical with regard to age, sex, BMI, diagnosis, surgical technique, implants, and peri-operative management. (Table 1) Pre- and post-operative clinical examinations at four weeks, six months, and one year were performed by a physician blinded to the surgical techniques. Pre- and post-operative radiographic measurements of the anterior-posterior mechanical axis and the sagittal tibial and femoral axes were evaluated by an observer blinded to the surgical technique. The Knee Society scoring system was used to assess clinical and functional outcomes relating to measures of range of motion, pain, knee stability, patient mobility, and movement independence. Aesculap Columbus™ cruciate-retaining, condylar implants were used in each patient. The Aesculap OrthoPilot™ navigation system was used for computer-assisted TKA. This study was approved by the Institutional Review Board of Northwestern University.

Results: Clinical and functional scores were not significantly different between CAS and manual patients at one and six months post-operative. (Table 2) The average change in clinical and functional scores from pre-operative to one and six months post-operative was also similar. (Table 3) Pain calculations were slightly higher (less pain) for CAS patients at one month post-operative, however no difference was noted at six months. (Table 2, 3) Range of motion was not significantly different at one and six months post-operative. (Table 2, 3) Mechanical axis, sagittal femoral axis, and sagittal tibial axis radiographic results were not significantly different. (Table 2) The number of units of blood transfused was slightly greater for CAS patients and tourniquet time was on average, twenty-seven minutes longer for CAS compared to manual TKA. (Table 2)

Discussion: Unlike the senior author's initial experience working with CAS, this study found no statistically significant radiographic alignment differences between TKAs performed using CAS and manual techniques.[10] This suggests that either external factors such as advancements in implants and mechanical alignment systems have resulted in manual TKA being performed more accurately, or that improvement in manual TKA technique has been realized through more than four years of extensive CAS utilization by the senior author. The instruments used in this study (intramedullary femoral alignment and extramedullary tibial alignment instruments) were similar to the mechanical alignment instruments used in the previous study. [10] Although advancements in implants and instruments have been made, mechanical alignment systems still have *inherent* limitations in their ability to accurately determine the location of crucial alignment landmarks.[10] These limitations have been confirmed in a number of studies that have demonstrated superior alignment outcomes with CAS as compared to manual instruments.[1-6,8,9] Clinical and patient-perceived functional results were not significantly different for CAS and manual TKA in this study. Outcome measures such as one's level of pain, range of motion, knee stability, mobility, and movement independence were not significantly different in early follow-up. One possible limitation of this study was that alignment results were based on radiographic measurements. The sensitivity of radiographic assessment of limb and implant alignment may not be great enough to distinguish small differences present between CAS and manual techniques. CT has been shown to be a more sensitive and effective method of determining alignment measurements.[2] However, even if standard radiographs are not sensitive enough to detect subtle differences in alignment, these differences were not significant enough to influence short-term clinical and functional results. This was a short-term follow-up study. The long-term success of TKA is highly dependent upon proper limb and implant alignment. Thus, it is possible that alignment differences that were too minor to be exposed by standard radiograph might result in long-term differences in the durability of the arthroplasty performed using CAS or manual techniques. This study suggests that there is intra-operative feedback and training effects associated with extensive use of a navigation system. We believe it is possible for refinements in alignment perception, improvements in intraoperative judgment, and advances in technique to evolve to the point that no significant differences in radiographic alignment are apparent between CAS and manual TKA.

Conclusion: There has been no previous study of the potential intra-operative training effects that CAS may provide to surgeons familiar with the basic TKA surgical technique. This study suggests that surgeons experienced in TKA surgery can improve the accuracy with which they perform the procedure to the point that that the radiographic and initial clinical and functional results with manual and CAS instruments are equivalent. This is possible when they receive the intra-operative training effects provided by working with CAS. The intra-operative feedback with regard to resection, implant, and limb alignment provided by CAS offers surgeons an opportunity to improve their judgment with regard to the accuracy with which they perform and evaluate each step of the TKA procedure. CAS should have a fundamental role in shaping the training of current and future TKA surgeons. It offers the possibility of enhancing the surgical technique and alignment perceptions of experienced surgeons and offers the potential to function as a highly effective teaching tool to train orthopaedic residents and less-experienced surgeons on how to perform knee reconstructions accurately.[7,11] Further work needs to be carried out to determine which steps of the TKA procedure are most affected by these training effects and how these effects can best be realized. Most importantly, methods need to be developed to provide the surgeon less experienced in TKA surgery with ways of receiving these intra-operative training effects, thereby reducing the variation in alignment outcomes.

B7-1

PRECISION OF THE POSITIONING OF AN UNICOMPARTMENTAL KNEE PROSTHESIS BY A MINI-INVASIVE NAVIGATED TECHNIQUE

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INTRODUCTION

Unicompartmental knee replacement (UKR) is accepted as a valuable treatment for isolated medial knee osteoarthritis. Minimal invasive implantation might be associated with an earlier hospital discharge and a faster rehabilitation. However these techniques might decrease the accuracy of implantation, and it seems logical to combine minimal invasive techniques with navigation systems to address this issue.

MATERIAL AND METHODS

The authors are using a non image based navigation system (ORTHOPILOT ™, AESCULAP, FRG) on a routine basis for UKR. The used version of the software helps the surgeon orienting the bone resections through a minimal invasive medial approach without splitting the quadriceps tendon or the vastus medialis muscle. The proximal tibial resection is performed with a conventional motorized saw blade guided by a free hand navigated orienting device. For the femoral resection, a bow is fixed by three percutaneous screws to the distal femur. The bow is navigated to be oriented along the knee flexion axis. A guide is fixed on the bow and oriented under navigation control to perform the distal femoral resection with a burr. Neither guides are fixed directly into the joint.

42 patients have been operated on in the 4 participating centers for an isolated medial osteoarthritis. There were 29 women and 13 men, with a mean age of 65 years. The post-operative coronal and sagittal orientation of both prosthetic components were measured, and the time to get 90° of knee flexion was recorded.

RESULTS

The mean coronal angle between the femoral component and the femoral mechanical axis was 89° for an expected goal of 90°. The mean coronal obliquity of the femoral component was 91°, for an expected goal of 90°. The mean coronal angle between the tibial component and the tibial mechanical axis was 86° for an expected goal of 88°. The mean coronal obliquity of the tibial component was 88°, for an expected goal between 85 and 90°. The mean sagittal obliquity of the femoral component was 6°, for an expected goal of 10. The mean sagittal obliquity of the tibial component was 88°, with an expected goal of 87. The patients achieved 90° of knee flexion after a mean period of time of 9 days.

DISCUSSION

The used navigation system is based on an anatomic and kinematic analysis of the knee joint during the implantation. The modification of the existing software for its use with a minimal invasive approach has been successful. It enhances the quality of implantation of the prosthetic components and avoids the inconvenients of a smaller incision with potentiel less optimal visuliazation of the intra-articular reference points. However, all centers observed a significant learning curve of the procedure, with a significant additional operative time during the first implantations. The postoperative rehabilitation was actually easier and faster, despite the additional percutaneous fixation of the navigation device.

CONCLUSION

This system has the potential to allow the combination of the high accuracy of a navigation system and the low invasiveness of a small skin incision and joint opening.

B7-2

MEDIAL UNICONDYLAR KNEE ARTHROPLASTY DECREASES PAIN AND IMPROVES FUNCTION: A PROSPECTIVE, SINGLE SURGEON REPORT ON 2-YEAR MINIMUM FOLLOW-UP

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INTRODUCTION

Unicondylar knee arthroplasty (UKA) has seen a resurgence in the past decade. Perpetuation of this trend can only be supported through prospective demonstration of efficacy with validated outcomes measures.

MATERIALS & METHODS

Twenty-five consecutive cemented medial Miller-Galante UKA's (Zimmer, Warsaw, IN) were performed in 24 patients (5 males/19 females; mean age of 66 ± 8 years). Average weight, height, and body mass index (BMI) of the patient population was 190 ± 33 lbs (Range, 145-260), 65 ± 4 in (range, 60-75), and 33 ± 5 BMI (range, 25-43), respectively. Average polyethylene thickness (as labelled) for this cohort was 8.3mm (range, 8-10mm). Outcomes were prospectively assessed via the SF-12, WOMAC, and Knee Society Score (KSS). No patients were lost to follow-up. Kaplan-Meier survivorship and Student's t-test were performed using GraphPad Prism 4 software (GraphPad Software Inc., San Diego, CA).

RESULTS

Minimum follow-up was 24 months with a mean follow up period of 32 (range, 24-40) months. One knee was converted at 6 months at another institution to a TKA. Kaplan-Meier survivorship analysis reported 96% survivorship at 40 months (95% CI). Of the 24 knees remaining, mean preoperative KSS and WOMAC pain scores improved significantly from 53 ± 7 (range, 37-67) to 91 ± 7 (range, 77-100) ($p<0.0001$) and from 41 ± 24 (range, 0-80) to 90 ± 13 (range, 60-100) ($p<0.0001$), respectively. Additionally, average SF-12 Physical Component scores significantly increased from 31 ± 8 (range, 18-51) at baseline to 45 ± 10 (range, 19-56) at time of follow-up ($p<0.0001$). Overall stiffness and physical function assessed via the WOMAC index also exhibited statistically significant improvement, bettering from mean baseline scores of 54 ± 24 (range, 0-100) and 52 ± 19 (range, 25-87) to 76 ± 24 (range, 50-100, $p<0.05$) and 82 ± 19 (range, 38-100, $p<0.0001$), respectively. No significant cement/bone interface radiolucencies were found upon thorough radiographic review at 2 years post UKA.

DISCUSSION & CONCLUSION

The significant improvements observed in knee function & stiffness, and decreases in pain at 2 years after medial UKA are encouraging. Coinciding results from the physical component of the SF-12 assessment indicate reassurance of physical improvements regarding patient lifestyle. 96% survivorship in the short term would be discouraging if not for the specific circumstances of the sole conversion to TKA (Worker's compensation/disability litigation and absence of significant improvement after conversion to TKA). This specific patient went against the advice of the operative surgeon and solicited a second opinion at an outside institution in conversion to a TKA despite markedly improved function (Pre-op/3 month post-op WOMAC and KSS of 30/75 and 60/91). Clinical and radiographic follow up will continue on a yearly basis in order to assess the long-term efficacy of medial UKA with the Miller-Galante prosthesis using strict patient selection criteria.

B7-3

IS MINIMALLY INVASIVE SURGERY-TOTAL KNEE ARTHROPLASTY (MIS-TKA) LESS INVASIVE THAN STANDARD TKA?

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BACKGROUND

With recent technical advancements, the number of operative manipulations in the knee joint by minimally invasive surgery- total knee arthroplasty (MIS-TKA) is now considered to be the same as that using standard total knee arthroplasty (S-TKA). The question still remains, however, if MIS-TKA improves recovery compared to S-TKA.

METHODS

We compared MIS-TKA and S-TKA patients' physical activity for 7 days preoperatively and 14days post-operatively as measured by an accelerometer. In the MIS-TKA group (n=10), mini-mid vastus approach was used, and in the S-TKA group (n=10), the medial para-patellar approach was used in this study. There was no significant difference in age at operation, body mass index, or pre-operative range of motion between these two groups.

RESULTS

Physical activity expressed as cumulative acceleration was significantly higher in the MIS-TKA than in the Standard-TKA group on postoperative days (POD1,2,3,4,5,10,11) ($p<0.05$). The recovery time, defined as the number of days required to achieve cumulative acceleration of 80% of the pre-operative level, was significantly shorter ($p<0.05$) in the MIS-TKA (3.0±3.3 days) group than in the S-TKA (7.0±3.5 days) group.

In the MIS-TKA group, on postoperative day 5, the physical activity value recovered to 100% compared with pre-operative physical activity. In the S-TKA group, however, even on postoperative day 14 recovery was only 97.7% of pre-operative values.

CONCLUSION

MIS-TKA appears to allow an earlier recovery after the operation than Standard-TKA. Less invasion to muscle during the surgery appears to contribute to shorter convalescence.