



# Poster

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## P1

### MINIMUM 15 YEAR FOLLOW-UP OF THE INSALL-BURSTEIN-1 TOTAL KNEE ARTHROPLASTY

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**INTRODUCTION:** This represents a 15-18 year follow up of one hundred metal backed, non-modular Insall-Burstein-1 posterior stabilized knee prostheses implanted in 86 patients from 1986-1989 and originally reported at 10-12 years.

**METHODS:** The original cohort (57 female; 43 male) had an average age at surgery of 69.7 years (range: 45-89). The primary diagnosis was osteoarthritis in 77 knees, inflammatory arthropathy in 17 and post-traumatic arthritis in the remaining 6 knees. Six failures occurred by 10 years (1 aseptic loosening, 1 patella fracture, 2 sepsis and 2 non-specific pain).

At 15-18 years (mean: 16.2 years) fifty patients (60 knees) had died, 18 knees were followed with clinical exam and radiographs, 13 by telephone, 3 were lost and 6 had failed by 10 years (see above). The average age of the surviving patients was: 82.1 years (range: 68.3-94.2).

**RESULTS:** Average Knee Society Scores (15-18 years) were 93.7 (clinical) and 57.9 (functional) in these aged patients. No new failures occurred and no additional surgeries were recommended or performed from 10-18 years. No case exhibited measurable polyethylene wear or osteolytic lesions (lucency measuring at least 10x 5mm with loss of trabeculation and sclerotic border, consistent with other authors' criteria). Using revision as endpoint, cumulative survivorship rate was 92.4% at 15 years.

#### **DISCUSSION:**

1. No new failures after 10 years.
2. Non-modular prosthesis had no failures due to osteolysis (unlike its modular counterpart).
3. Prosthesis likely to outlive the patients when classical indications for age and activity (over age 65, sedentary) are respected.

## P-2

### WHERE IS THE BALANCE FOR ANTIBIOTIC CONCENTRATION IN METHYLMETHACRYLATE CEMENT?

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Methylmethacrylate cement (PMMA) is widely used in joint replacement surgery as a depot of delivery for antibiotics. Several studies investigating *in vitro* elution rates of common antibiotics mixed in PMMA or calcium sulfate, have demonstrated a marked variability in elution depending on volume, exchange rate, and physical environment. The antibiotic concentration can reach intermittent systemic toxicity and prolonged local effects. The main objective of this study was to investigate whether local doses of various antibiotics theoretically released from PMMA had any effect on local cell populations. The study investigated the influence of various concentrations of three commonly used antibiotics, namely vancomycin, ciprofloxacin, and tobramycin on bone cells. The findings of this study have pertinent clinical relevance as cell proliferation is critical for the process of osseointegration of press fit components and fracture healing. These results are crucial for determining the optimal antibiotic composition of bone cement that would provide an ideal balance between the microbicidal effects and the host cellular toxicity.

**METHODS:** *Cell lines* MC3T3-E1 preosteoblast cells, MLO-A5 osteocyte cells, and N1511 prechondrocyte-like cells were cultured in DMEM. *Treatment* Cells were passaged into 24 well plates, and after 12h, the culture medium was exchanged with fresh medium supplemented with Ciprofloxacin (0-1000 µg/ml, Cipro), Ofloxacin (0-1000 µg/ml, Oflox), Tobramycin (0-4000 µg/ml, Tobra), or Vancomycin (0-8000 µg/ml, Vanco) every 24h for 3 days. *Cell proliferation/toxicity assays:* MTT colorimetric assay (Molecular Probes) every 24h was used to measure cell viability and proliferation by normalization to control cultures. Lactate dehydrogenase activity was used to assess direct cell death.

**RESULTS:** The effect of Oflox on cellular morphology of MLO-A5 cells was first studied. Osteocytes cultured with increasing dosages of Oflox showed a drastic change in morphology, and cell numbers. In the presence of 25 µg/ml of Oflox, cells are abundant and exhibit cuboidal, well-spread cellular morphology. In contrast, at 1mg/ml Oflox, the cells, if present, appear non-viable with a globular and detached morphology. When exposed to Cipro, osteoblast/osteocyte and chondrocyte cell lines show marked inhibition of cellular proliferation. Cipro concentrations of 25 µg/ml induce over 25% decrease in osteoblast and chondrocyte numbers. With Vanco much higher dosages were needed to cause inhibitory effects. Vanco concentrations higher than 100-250 µg/ml showed initial inhibition of proliferation, with 8 mg/ml inducing >50% cell loss. Tobra showed similar toxicity to Vanco. Both cell populations appeared less sensitive at lower dosages, with a robust effect observed in osteoblasts between 2-4 mg/ml. The chondrocytes, in contrast, did not show much sensitivity to the Tobra, with a 20% loss in cell numbers observed at 1- 4 mg/ml.

**DISCUSSION:** High local concentration of Cipro, and to a lesser extent Vanco and Tobra were seen to have detrimental effects on osteoblastic and chondrocytic cellular proliferation. Further, the morphology of these cells appeared to be influenced by the presence of antibiotics even at lower concentrations. Further studies are needed to determine the optimal concentration of antibiotics being impregnated into PMMA so that effective infection treatment can be achieved without imparting local cellular toxicity.

## P3

### PERI-PROSTHETIC INFECTION MODEL IN RATS

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Few readily usable animal models are currently described, with no models in smaller mammals like the rat. We describe a rat periprosthetic infection model that appears simple and consistent.

**METHODS:** 1mm diameter Ti90Al6V4 (Ti, Goodfellow) rods were passivated, silanized with APTS, reacted twice with AEEA, and covalently linked with Vancomycin. *Animal Testing.* All protocols were approved by the IACUC of Thomas Jefferson University. Wistar rats (Charles Rivers), 300-350 g, were anesthetized with IP ketamine/xylazine, with maintenance isoflurane, and buprenorphine for pain control bid as needed. Infection was induced by injection of  $10^3$ ,  $10^5$ ,  $10^7$  CFU *S. aureus* in 150uL of saline into the femoral canal with the opposite side without bacteria left as control. Control Ti were sterilized by incubation in 70% ethanol for 15 min, rinsed 3X with PBS, and implanted retrograde in the femoral canal. At harvest, animals were euthanized with CO<sub>2</sub>, radiographed, femur dissected, microCT. The pin was removed and rolled on plate, followed by sonication & serial dilution plating for CFU counts.

**RESULTS:** We have tested various methods of inducing bone infection in the rat, including culturing a biofilm on the rod for 72 h, dipping the rod in active bacterial cultures, and injecting the bacteria directly into the femoral canal. Rods with expected biofilm on the surface produced 50% infection in 1 of 2 animals. The most consistent and successful method of inducing periprosthetic infection in the rat seemed to be direct injection into the femoral canal with all tested doses showing good results. The higher  $10^7$  CFU/mL causes extensive distress in the animal with extensive swelling and loss of weight bearing. The infection was manifested radiographically within the first 4 days post-operatively. At week 1, the upper two doses showed infection. Upon harvesting of the higher dose group, severe bone loss was observed with extensive puss and fibrous inflammatory tissue. However, no cross over of infection was observed from the infected side to the control side. The low dose group showed mild bone infection, some bone remodeling, with minimum bone loss.

**DISCUSSION:** Few periprosthetic infection models exist in smaller mammals, and are limited to rabbits, dogs, or sheep. Considering that periprosthetic infection is currently the second most common complication after joint replacement, the need for a good and inexpensive animal model is crucial. We have developed a new model of periprosthetic infection in rats, which are readily available, relatively inexpensive, and easy to manage. However, the rat immune system is highly developed and able to resist severe microbial attack. We have consistently obtained bone infection after injecting directly into the femoral canal as little as  $10^3$  CFU in 100 uL of saline. Lower doses have proved unsuccessful. With increasing dose the time line of infection change little, with most drastic differences seen in volume of bone loss and overall bone destruction. At the same time, even with the higher doses the risk of systemic infection and septicemia is very small, and at no time any cross over infection was observed. The proposed rat model of peri-prosthetic infection may provide a ground for more studies to elucidate the mechanisms of peri-prosthetic infection and develop new strategies against implant association infections.



## P4

### VANCOMYCIN-MODIFIED IMPLANT INHIBITS BACTERIAL SURFACE COLONIZATION AND INFECTION DEVELOPMENT

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Periprosthetic infection is a severe consequence of implant insertion. We hypothesized that implant surfaces that are covalently modified with antibiotics can inhibit the development of peri-prosthetic infection and bone destruction.

**METHODS:** *Modification of Ti alloy.* 1mm diameter Ti90Al6V4 (Ti, Goodfellow) rods were passivated, silanized with APTS, reacted twice with AEEA, and covalently linked with Vancomycin. *Animal Testing.* All protocols were approved by the IACUC of Thomas Jefferson University. Wistar rats (Charles Rivers), 300-350 g, were anesthetized with IP ketamine/xylazine, with maintenance isoflurane, and buprenorphine for pain control bid. Infection was induced by injection of 1500 CFU *S. aureus* into the femoral canal. Control Ti and TiVAN were sterilized by incubation in 70% ethanol for 15 min, rinsed 3X with PBS, and implanted retrograde in the femoral canal. At harvest, animals were euthanized with CO<sub>2</sub>, radiographed, femur dissected, microCT performed. The pin was removed and rolled on plate following by sonication and serial dilution plating for CFU counts. Furthermore, the femurs were decalcified with EDTA, sectioned with paraffin, and evaluated for bone infection.

**RESULTS:** All animals showed signs of infection within the first few post-operative days with increased swelling surrounding the femur and limited mobility. All animals were partially weight bearing, mainly with preference for the control side. At 1 week 75% of the animals showed signs of periprosthetic infection easily diagnosable by radiography. 92% of the animals the left and right sides showed observable differences, all indicating infection on the control side. In one animal the infection manifested on the treatment side partially due to the pin insertion penetrating the bone cortex. In those cases, periosteal elevation and enlargement of the femoral canal were most common. In 30% of animals advanced bone destruction was seen in the form of lytic areas, bone cysts, and aggressive remodeling. The ratios progressed similarly to week 2 through 4. More aggressive remodeling is observed with time, with no change in infection rates or ratios. At harvest, infection was clearly prevalent on the control side, the treatment side receiving the vancomycin-modified rod showed decreased signs of infection compared to the control limb. After culturing the implant, significantly fewer bacteria were present on the vancomycin-modified rod. Furthermore, those findings were consistent with the histology and microCT of the samples analyzed.

**DISCUSSION:** We have previously reported on the engineering of a new implant modification that incorporates a nanoscale surface of covalently linked antibiotics. In this report we test our surface in a mammalian periprosthetic model, showing successful inhibition of peri-prosthetic infection. Radiologically, the control side was easily distinguishable from the treatment side with the vancomycin-modified rod. Bone destruction was prevalent on the control side. Furthermore, significant decreases in bacterial numbers were observed on the vancomycin modified rod compared to control rod. Respectively, more bone loss was observed in control femora compared to the femora that received the vancomycin modified rod. Thus, this implant has a lively potential to actively influence the near future of implant design and possibly prevent or even eradicate clinical implant associated infection.

## P5

### ANTIBIOTICS INTRINSIC TO IMPLANT PROVIDE HOPE

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Periprosthetic infection (PPI) continues to pose a challenge to orthopedic surgeons, as current management strategies remain imperfect. We have described a novel technique of chemically tethering antibiotics to titanium powder. Now, we have hypothesized that antibiotics (1) can be covalently attached directly to the implant surface, (2) will retain their activity against the target microorganisms, (3) will be stable over time, and (4) will have minimum host cell toxicity.

**MATERIALS:** Modification of Ti. 1mm diameter Ti90Al6V4 (Ti, Goodfellow) rods were passivated, silanized with APTS, reacted twice with AEEA, and covalently linked with Vancomycin. VAN immunofluorescence. Control and VAN-modified Ti rods (TiVAN) were incubated with mouse anti-VAN IgG (1:300, US Biologicals), 4°C, 12h, followed by AlexaFluor 488-coupled donkey anti-mouse IgG (1:300, Molecular Probes), 1 h. Short term stability. TiVAN was incubated in Luria-Bertani broth containing *S. aureus* ( $C_i \sim 10^4$  cfu) for 6 days, air dried, washed extensively with PBS, vortexed, washed with 1% (v/v) Triton X-100 in dH<sub>2</sub>O, 70% ethanol in dH<sub>2</sub>O, and stained for VAN. Antibiotic Activity. Control Ti and TiVAN were sterilized by incubation in 70% ethanol for 15 min, rinsed 3X with PBS, and incubated with *S. aureus* ( $C_i=10^4$  cfu) in LB, 37°C, 24 h. Cell toxicity. MC3T3-E1 preosteoblast-like cells were cultured in Dulbecco's Modified Eagles Medium with 10% FBS and passaged into 24 well plates. Ti or TiVAN rods were placed in the wells and incubated for 3 days to assess cell adhesion and proliferation on the surface. Cells were labeled with CellTracker Green (Molecular Probes) for 5 min prior to visualization by fluorescence.

**RESULTS:** Surface modification Ninhydrin assays to determine aminosilanization and Fmoc quantifications to determine AEEA addition yielded  $1.27(\pm 0.21) \times 10^{-16}$  mol/ $\mu\text{m}^2$  and  $1.37(\pm 0.33) \times 10^{-16}$  mol/ $\mu\text{m}^2$  respectively, predicting >95% efficiency for each synthesis step. Antibiotic coverage. Stained by immunohistochemistry for vancomycin, The TiVAN rod shows intense, diffuse staining with areas of focal differences perhaps due to local heterogeneity of the Ti rod; the control Ti surfaces exhibit no specific fluorescent signals. Microbicidal activity. We next tested if VAN retained its activity after chemical bonding to the rod. After 24h of exposure to high doses of *S. aureus*, the TiVAN shows background fluorescence over the surface, suggesting that bacterial adhesion/proliferation is minimal. In contrast, the control Ti rods show intense fluorescence with *S. aureus* slime apparent. Host cell tolerance. To test the effects of the surface modification on osteoblast-like cell adhesion, MC3T3-E1 cells were cultured in the presence of Ti and TiVAN rods and cellular adhesion visualized by CytoTracker Green staining. Both rods showed extensive colonization by the osteoblast-like cells *in vitro*, suggesting that the TiVAN surface was not adversely affecting osteoblastic viability.

**DISCUSSION:** We have described a novel surface modification on Ti implants that renders them bactericidal. The covalent chemical bonding confers stability to the antibiotic in time, potentially allowing coverage for multiple assaults by infectious organisms. Thus, our proposed modification in surface design serves as a starting point for the development of a new generation of implants that target biological activities to sites of physiological importance.

## P6

### VANCOMYCIN-MODIFIED RODS INHIBIT BACTERIA EVEN AFTER SERUM COATING

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We have hypothesized that a surface modified with covalently-bound vancomycin will be bactericidal, thus preventing bacterial attachment and biofilm formation. We have tested the activity of such a surface against *S. epidermidis* and we have asked how exposure to serum proteins affects availability and activity of vancomycin (Vanc).

**METHODS:** Modification of Ti alloy Passivated Ti90Al6V4 (Ti, Goodfellow) surfaces were aminopropylated with aminopropyl-triethoxysilane followed by Fmoc coupling of two aminoethoxy-ethylacetic acid linkers and vancomycin. Implant coverage. Rods were incubated in FBS, washed and stained with antibodies to Vanc, Alb, and fibronectin (FN). Indirect immunofluorescence. Rods were incubated with mouse anti-Vanc IgG, goat anti-FN IgG, or rabbit anti-BSA IgG (1:500), 2h, followed by AlexaFluor 594-coupled donkey anti-mouse IgG (1:300), AlexaFluor 647-coupled donkey anti-rabbit IgG, AlexaFluor 488-coupled donkey anti-goat IgG (1:500, Molecular Probes), 1h. Bactericidal Activity. Weighed control and Ti-Vanc were sterilized with 70% ethanol, 30 min, washed 5X with PBS, and incubated with  $10^4$  cfu of *S. epidermidis* under static conditions. At 2, 5, 8, 12, and 30 h, six rods were removed, washed 5X with PBS, and three rods used for bacterial adhesion/viability and three used for total bacterial numbers. Adherent bacteria were suspended by sonication in 1 ml 0.3% Tween 80 in TSB, 5 min, and vortexing, 5 min. Bacterial counts were determined by triplicate plating of serial dilutions on TSB agar (countable range = 30 – 300 cfu/plate). Total bacterial numbers were expressed as a function of pin weight. Rods were washed 6X with PBS to remove non-adherent bacteria, stained with the Live/Dead<sup>®</sup> BacLight<sup>™</sup> Viability Kit (Molecular Probes), 15 min.

**RESULTS:** On Ti-Vanc rods, only small areas of fluorescence are apparent, suggesting that Vanc is potently inhibiting bacterial colonization. In contrast, control Ti rods are extensively colonized, as evidenced by intense green staining, and this colonization increases with time. Numbers of adherent *S. epidermidis* were also determined by direct counting, with Ti-Vanc rods showing significantly fewer adherent bacteria than control rods. Because, in a physiological environment, implants will be coated with serum proteins, we next asked if Vanc coverage affected the adsorption of serum proteins and if this protein affected Vanc activity. After incubation with FBS, both rods are coated with FN and Alb. Interestingly, the signal for these proteins is more intense on Ti-Vanc rods possibly indicating increased coverage. Importantly, serum incubation did not significantly alter the intensity of the Vanc fluorescence, suggesting that this coverage with serum proteins did not alter Vanc accessibility. To test this, Ti-Vanc rods were incubated in FBS or DIH<sub>2</sub>O for 24h and challenged with *S. epidermidis*. Ti-Vanc potently inhibits *S. epidermidis* colonization, confirming the activity of the Ti-Vanc even when coated by serum proteins.

**DISCUSSION:** We have described a surface modification that allows Ti rods to resist colonization and ultimately biofilm formation by large numbers of contaminating *S. epidermidis*, despite the acquisition of an abundant FN and Alb coating, as would happen during surgical insertion of the implant. Because these surfaces retain their antibiotic, problems of tissue toxicity and bacterial resistance are minimized. Such surfaces hold great promise for the prevention and treatment of periprosthetic infections.

## **P7**

### **BIOMECHANICAL DIFFERENCES AT THE CEMENT-BONE INTERFACE OF POLISHED AND ROUGHENED TAPERED STEMS CEMENTED IN COMPOSITE FEMURS**

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#### **INTRODUCTION**

Different surface finishes of cement-fixed femoral stems result in different outcomes. However, the mechanical behaviors of cement at the cement-bone interface have not been confirmed in different surface finishes. This study investigated the mechanical influence of different surface finishes for stems at cement-bone interfaces using a biomechanical model.

#### **MATERIALS AND METHODS**

Number 2 (small) and number 3 (large) size collarless polished tapered (Polish) stems (CPT®, Zimmer, Warsaw, IN, USA) and rough processed CPT® (Rough) stems were fixed to composite femurs soaked in vegetable oil using vacuum-mixed bone cement. One Hz dynamic load (3000N) was applied to a metal head attached to the stem 106 times. The load was applied 16 hours a day and no load was provided for the next 8 hours. Femur temperature was maintained at 37°C during testing. Compressive forces during load term, stress relaxation values during unload term and cement movement toward the exterior of the canal were measured via 8 pairs of rods placed at the cement-bone interface. Stem subsidence was also measured.

#### **RESULTS**

Final stem subsidence in small and large stems was 1.18mm and 0.52mm for the Polish stem, and 0.27mm and 0.33mm for the Rough stem, respectively. Force and cement movement were most obviously at the proximal medial part. In the Polish stems, compressive force and stress relaxation values increased gradually over time, however, they decreased in the Rough stems. Final compressive forces for small and large stems in Polish stems were 435N and 179N, and they were 11.4-fold and 3.2-fold greater than those in the Rough stems, respectively. Cement movement to the exterior of the canal in the Polish stems was also 7.4-fold and 2.6-fold greater than those in the rough stem, respectively. Stem subsidence in the Polish stems demonstrated significant positive correlations with compressive forces.

#### **DISCUSSION**

Mechanical behaviors were different between polished and rough surface finishes in femoral stems. In the Polish stems, increasing compressive forces and stress relaxation values over time were observed in closely simulating biological conditions, maintaining a temperature of 37°C, wet bone and with simulated sleep. This could maintain the cement-bone interface against failure. On the other hand, in the Rough stems, decreasing compressive forces and stress relaxation values may be defeated by shear force and could cause early mechanical failure at the cement-bone interface.

These different mechanical behaviors in different surface finishes were considered to be related to the different outcome in cemented stems.

#### **CONCLUSION**

Compressive forces and stress relaxation values at the cement-bone interface increased in the Polish stems, however, they decreased in the Rough stems gradually over time in a biomechanical study.

## P8

### LESS INVASIVE TOTAL KNEE ARTHROPLASTY: EXTRAMEDULLARY FEMORAL REFERENCE WITHOUT COMPUTER NAVIGATION

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Femoral intramedullary canal referencing is utilized by most of the total knee arthroplasty (TKA) systems. Violation of the canal is performed in order to engage rod instruments in the femoral diaphysis and to refer of the anatomical axis of the femur. Fat embolism, activation of the coagulation cascade, and bleeding may occur from the reamed femoral canal. The purpose of our study was to validate a new set of “minimally-invasive friendly” instruments which allow to prepare the femur without violating the intramedullary canal. Twenty-five consecutive patients undergoing primary TKA through a mini-subvastus approach were enrolled in the study after informed consent had been obtained. Results of this cohort (group 1) were compared to another contemporary group (group 2) of 25 TKAs operated by the same surgeon using intramedullary instruments. The two groups were matched for gender, deformity, degree of arthritis, and surgical approach. Reliability of the new extramedullary set of instruments was first tested in ten cadaveric limbs. Preoperative long weight-bearing AP and lateral view of the knee were obtained taking care of neutral limb positioning. Template of the mechanical and anatomical axis were performed. Distal femoral resection was planned according to the template, and considering a bone cut perpendicular to the mechanical axis of the femur. Measurement from the template were reproduced on the distal femoral cutting jig. Flexion-extension control of the distal femoral resection was obtained using the anterior meta-diaphyseal cortex reference. Depth of resection, and varus-valgus angulation were selected according to the previous measurements and referring over the most prominent distal femoral condyle. A double check was performed using an extramedullary rod referring two and a half finger-breaths medially to the antero-superior iliac spine. Postoperative blood loss, pain, swelling, functional recovery, and complications were recorded. Radiographic alignment was measured with long film. Mechanical axis was within  $0\pm 2^\circ$  in 88% of group 1 and 84% of group 2 ( $p>0.05$ ). There were no difference between the two groups regarding the operative time. In group 1, postoperative blood loss (740 vs 820 mL) was reduced but this difference did not reach the statistical significance ( $p=0.07$ ). No difference was found in terms of postoperative pain, knee swelling, and functional recovery. Extramedullary reference with careful preoperative templating can be safely utilized during total knee arthroplasty. Avoiding the violation of the femoral canal may enhance the benefits of a less invasive approach.

## **P9**

### **GENDER-SPECIFIC TOTAL KNEE ARTHROPLASTY**

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One hundred consecutive gender-specific total knee arthroplasty implantations will be described. The aspect ratio of the prosthesis is 0.9, as opposed to the 0.8 common to most current implants. The additional features being evaluated in this design are a thinner trochlear groove with an increased angulation of the trochlear sulcus to accommodate the variations in female anatomy. The evaluation will include the traditional Knee Society and HSS scores, as well as additional criteria directed at the specific design features of the new implant. Radiographic and clinical techniques for predicting the percentage of female as well as male patients in whom this particular customized prosthetic design is appropriate will also be offered. Pre and postoperative X-Ray analysis as well as specific surgical techniques to enhance the design components of the implant will be presented.

## **P10**

### **A SINGLE USE DEVICE TO REDUCE STRESSES GENERATED IN HIP PROSTHESIS SURGERY, LOWERING THE INCIDENCE OF INTRA-OPERATIVE FEMORAL FRACTURES**

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Hip prosthesis implantation is one of the most common operations carried out today. The hip stem implantation technique requires the removal of the femoral head followed by the incremental impaction of a smooth tamp or broach. This creates an opening in the intramedullary canal to form an insertion site for the hip prostheses within the femur.

The impaction of such devices results in high stress generation within the femur which can result in intra-operative femoral fractures. This effect may be exacerbated by the accumulation of bone debris from the cutting action. A further possible complication of these reusable devices is the potential for cross-contamination due to inadequate sterilisation.

The present work aims to address these potential problems by developing a lightweight, cost effective, efficient single use hollow broaching device.

The optimum cutting characteristics for the single use device were ascertained using a dedicated planing device. The blade angle (the angle that the blade subtended the bone) was varied between 10 and 90 degrees and the bone was shaved, whilst the cutting force was monitored. Additional tests were conducted with serrated blades with blade angles of 10 and 30 degrees respectively.

Upon ascertaining the optimum cutting form, a single use device was manufactured from sheet steel that incorporated these features. A direct comparison was made between a standard stainless steel broach and the single use broach via impact tests on analogue sawbone. Strain development in analogue bone and penetration due to impact/broaching was monitored. Each sawbone was strain gauged to allow strain to be monitored in the most highly stressed region of the bone (below the femoral neck on the medial side).

Shallower cutting angles gave the least force required to shave the analogue bone. The use of a serrated blade further reduced the force requirement. As expected, the trabecular bone tissue required less force to remove material than cortical bone, for which the results were less consistent.

Impact tests demonstrated that the rasp was more efficient at penetrating the sawbone intramedullary canal, achieving up to 60% increased penetration for the same number of impacts. Using a hollow rasp, the contents of the intramedullary canal can potentially be removed rather than compacted leading to lower instantaneous and residual strains.

The total strains induced as a result of solid broaching were higher than those from rasping (up to 350%). In addition, the strain reached an equilibrium sooner using the hollow rasp. This is probably due to the thinner, more flexible rasp taking up some of the strain in compression. Up to ten impacts were required by the solid broach before the strain induced by an impact did not increase by more than 200 microstrain in the most heavily strained region of the bone. Conversely the hollow rasp tended to induce the maximum strain within 6 impacts. These results indicate that in the clinical situation, less damage would occur in the surrounding tissue, and the possibility of initiating fracture would be reduced.

## P11

### A STUDY OF CORRELATION BETWEEN MICROMOTION AND INTERFACIAL FAILURE IN CEMENTED HIP ARTHROPLASTY

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Initial stability of cemented hip arthroplasty is considered as an effective indicator of its long-term clinical success. Especially interface micromotion has been widely used to estimate the initial stability. In this study, we investigated the correlation between micromotion and interfacial failure.

First, we measured interface micromotion using small and light custom-made sensor in vitro. For the measurement, the stems were implanted in 10 cadaver femurs and four sensors were installed at the anterior-proximal, anterior-distal, posterior-proximal and posterior-distal locations. The implanted femur was loaded at the femoral head by INSTRON 8874 with 1Hz cyclic load ranging between 200N and 3 times body weight. After micromotion measurement, stems were pulled out and femurs were cut into 5mm\*10mm segments near the measurement location. We obtained the cross section images using the fluorescent microscopy (Nikon Eclipse TE300). From the images, cracks and cement area including the interdigitated area were identified visually. And we measured the cement crack length and cement mantle area. Crack length-density was calculated by dividing total crack length by cement mantle area to denote the interface status.

The interface micromotions were detected at every specimen. Even the cement-bone interface which is considered well inter-locked showed some micromotion. From the cross section images, some defects including voids and cracks were founded. Cracks initiated at trabecular bone, void, mid-mantle or each interface. The cement-bone interfaces were maintained well interlocked macroscopically. The average crack length density is 0.0335mm/mm<sup>2</sup>. Also, the cement crack did not correlate with the micromotion (R=0.22).

We measured the crack length density at the bone-cement interface after measuring interface micromotion. The interface micromotions were detected at every specimen. However, the magnitude of cement crack did not correlate with the micromotion. It may imply that the measured micromotions are not directly induced from the interface failure.



## **P12**

### **THROMBOPROPHYLAXIS WITHOUT ROUTINE ANTICOAGULATION IN PRIMARY HIP ARTHROPLASTY: IS IT SAFE?**

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#### **A. INTRODUCTION**

Hip arthroplasty procedures are associated with the risk of venous thromboembolism (VTE). The search continues for the ideal combination of agents and factors (chemical, mechanical, surgical and anesthetic) that offer efficient thromboprophylaxis with the least risk of adverse effects. The aim of the present study is to assess if a combination regime of hypotensive epidural anesthesia, early mobilization, elastic graded compression stockings and aspirin (or other oral antiplatelet medication) provide safe and effective thromboprophylaxis in a consecutive group of patients undergoing unilateral hip arthroplasty.

#### **B. MATERIAL AND RESULTS.**

This is a retrospective review of the incidence of DVT in 228 consecutive unilateral primary hip arthroplasty procedures performed by one surgeon (DJWM) managed with no anticoagulants. There were 144 Birmingham Hip Resurfacing (BHR) procedures and 84 uncemented total hip replacements, all performed through a posterior mini incision approach. Duplex ultrasound scan screening for DVT was performed in all patients between the 4th and 6th post-operative day.

All patients were reviewed at a follow-up clinic 6 to 10 weeks after the operation. In addition a questionnaire response was obtained after the end of 12 weeks. There was no case of symptomatic DVT or pulmonary embolism. No above knee DVT was found in any patient.

#### **C. RESULTS**

The overall incidence of below knee DVT was 11% (25 of 228), 9.7% (14 of 144) in the BHR group and 13.1% (11 of 84) in the uncemented total hip arthroplasty group.

#### **D. DISCUSSION.**

The limitations of the study include the small numbers of patients of primary hip arthroplasty in a single centre, single surgeon series. However, the fact that, a low incidence of VTE is possible with this regime of prophylaxis wherein patients are not subject to the much higher risks of bleeding that are attendant with anticoagulant usage, cannot be ignored.

## **P13**

### **THE VALIDITY OF SERUM AS A SURROGATE MEASURE OF SYSTEMIC METAL EXPOSURE**

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#### **A. Introduction**

Metal ions generated from metal-metal joints are transported in plasma and within cells. Whole blood (WB) analysis is a good measure of systemic metal exposure because it includes both intracellular and extracellular compartments. Analysis of whole blood is technically more challenging than serum. But can serum levels be considered equivalent to whole blood levels in the assessment of systemic metal exposure?

#### **B. Material & Methods**

262 concurrent WB and serum specimens from patients after metal-metal hip arthroplasty, were analyzed for metal levels by high-resolution mass-spectrometry (reporting limits 0.06 $\mu$ g/l for serum and 0.1 $\mu$ g/l and 0.2 $\mu$ g/l for WB cobalt and chromium respectively). The relationship between serum and WB levels were studied using the criteria of Lee and the Bland-Altman limits of agreement.

#### **C. Results**

Mean WB and serum chromium concentrations were 2.2 and 4.2 $\mu$ g/l ( $p < 0.001$ ). Corresponding values for cobalt were 2.4 and 3.2  $\mu$ g/l ( $p < 0.001$ ). A normalized scatter shows poor congruence between whole blood and serum levels especially at lower concentrations. Both cobalt and chromium measurements fail on the interchangeability criteria of Lee by virtue of showing significant mean differences and a systematic bias. Bland and Altman analysis shows the limits of agreement between serum and WB are unacceptably wide (in excess of  $\pm 65\%$  for cobalt and  $\pm 85\%$  for chromium) suggesting poor agreement.

#### **D. Discussion & Conclusions**

The proportion of metal ion levels in serum and blood cells shows great variability. With advances made in mass-spectrometry, poor instrument sensitivity is a non-issue. Is there then a case for continued use of serum as a measure of systemic metal ion exposure? It can be justified only if serum levels show good agreement with WB levels throughout the range of measurements. Concurrent analysis of serum and whole blood metal ion concentrations in the present study, do not show such an agreement with four methods of testing, suggesting that serum metal concentrations cannot be reliably used as an instrument to measure systemic metal ion exposure.

## **P14**

### **ACTIVITY GUIDELINES FOR HIP AND KNEE ARTHROPLASTY PATIENTS – ARE THEY VALID...OR WORTHWHILE?**

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Elting, James

The “return to activity and sport” advice given to Total Hip and Knee patients must be a combination of : 1) The surgeon’s experience 2) Scientific data 3) The patient’s abilities, and 4) Published clinical information. Too often, the guidelines promulgated in the literature reflect more an opinion poll of Orthopaedic Surgeons rather than the evolution of the art and science of joint arthroplasty.

Since the advent of the joint arthroplasty 35 years ago, prosthesis fixation and alignment have become more reliable even as component design, material, and manufacture have greatly reduced the potential for wear. Modern bearing surfaces generate fewer wear particles over time; and contemporary fixation techniques lessen the risk of mechanical loosening or limb threatening osteolysis. However, as wear is dependent upon the magnitude of cyclical load over time, the decrease in age and increase in activity of our patient population must be considered. Likewise, the patient’s experience and ability in a specific sport cannot be overlooked in formulating advice.

Unfortunately, the scientific literature is not directly helpful, as the wear reported from bench testing or computer modeling cannot be correlated exactly to the in vivo situation. For example, rest, extremes of motion, and peak loads are not measured. Calculations of joint reactive force in various sports activity are reliably measured, however, and some helpful inferences can be made.

I believe a new algorithm for dispensing advice regarding activity after hip and knee replacements must be encouraged, as should more work such as Schmalzried’s pedometer study. All of this, or course, with the understanding that the patients will do whatever they feel comfortable doing...including some very strenuous occupations.

## **P15**

### **MID-TERM RESULTS OF A NOVEL LATERAL FLARE NON-CEMENTED HIP STEM**

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#### **A clinical, radiographic and densitometry study**

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#### **Background:**

Over the past decade, several design modifications have been introduced for uncemented femoral stems intended to increase initial stability by virtue of a tighter “press fit”. These designs may be classified into two general categories: anatomic and straight. The purpose of this paper is to report the clinical, radiographic and periprosthetic densitometry results of a novel cementless stem design that incorporates a proximal lateral extension (“lateral flare”) ensuring a high metaphyseal fit.

#### **Methods:**

Fifty-eight consecutive patients who received a non-cemented, proximally porous coated ‘lateral flare’ hip stem were followed for an average of 4.3 years (range 36-70 months). Patients were clinically and radiographically followed at 3 weeks, 3 months, 6 months, 1 year and yearly thereafter. In addition, a subset of 18 consecutive patients (20 hips) was studied with dual X-Ray Absorptiometry Scans (DEXA) at the same intervals during the first year and at 24 months after surgery.

#### **Results:**

The average pre-operative Harris Hip Score was 47 (range 36-58). This increased to an average of 97 (range 87-100) at the latest follow-up. There were no cases of aseptic or septic loosening. Two patients were excluded from further subsidence evaluation after each sustained a periprosthetic fracture due to a significant trauma that occurred at 26 and 48 months after the index operation respectively. The average subsidence of all patients at the 3 year follow-up was 0.51 mm (SD 0.31 mm). Radiographically, there were signs of osseointegration in all cases with densification of the cancellous bone underneath the lateral flare of the hip stem in Gruen Zones 1 and 2, as well as medially in Zones 6 and 7. The periprosthetic bone densitometry data showed more than 95% of bone stock preservation proximally 24 months after surgery with greater gains underneath the lateral flare of the stem, confirming the radiographic and clinical observations.

#### **Discussion:**

The extended lateral proximal geometry of this stem design appears to afford both initial and long term component stability as reflected by the low subsidence values over time. The maintenance of periprosthetic bone stock over time and the absence of stress shielding can be explained by the predominantly proximal loading pattern intended by this stem.

## **P16**

### **DEFINING THE ROLE OF MODULAR STEM DESIGNS IN THA**

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### **INTRODUCTION**

Modularity or multi-piece stems are becoming commonplace in THA with virtually all implant companies offering one version or another. Therefore the role of modularity would seem to be firmly established, but what if any limits or contraindications should be considered in light of increased patient related activities?

### **METHODS**

This paper is a follow-up to previous work by the authors intended to be a concise review of historical perspective, current trends, surgical experience, and results in using a variety (seven) of modular stems.

Surgeon authors have implanted over 3,000 modular stems since 1984 for both primary and revision THA. This paper will highlight experience for 1,900 stems used for primary THA in both cemented and cementless cases as they relate to femoral component failure (fracture).

Design, material properties, mechanical testing, surgical technique and clinical/surgical results will be reviewed.

### **RESULTS**

Four femoral components failures have occurred. One in a c.c. proximal modular neck cemented stem. Three in a proximal modular titanium neck cementless stem.

Both of these devices were immediately recalled from the market. Redesigned and introduced only after significant mechanical features were improved.

### **DISCUSSION**

Results demonstrate the viability of stem modularity in both cemented and cementless THA.

Overall modular designs have made THA easier, more reproducible and improved outcomes. However some designs have not functioned as well.

Historical review is invaluable in providing guidelines as to component design, indications and contraindications.

## **P17**

### **THE EFFECT OF KNEELING BEHAVIOR ON THE TOTAL KNEE ARTHROPLASTY USING FINITE ELEMENT ANALYSIS**

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As a result of technological advancement, the total knee arthroplasty (TKA) has become reliable surgery about pain relief. To date, the high performance of TKA such as kneeling has been inquired for the next stage of TKA. Mechanical effect of upright kneeling on patellar and tibial polyethylene inserts and posterior tibial translation (PTT) after TKA are unknown. The purpose of this study is to evaluate the effect of kneeling on the different type of TKA prostheses using finite element (FE) analysis.

Two-dimensional FE models were created for three different types of knee prostheses, cruciate retaining (CR), posterior stabilized (PS), highly conforming (HC) and adapted to quasi-3D models by setup the element depth and side-plate. The femur and tibia were constrained to axial direction, respectively. The PS model had a posterior cruciate ligament element. Anterior load of 600 N was applied to base plate that was 1) contacted to tibial tuberosity or 2) contacted to tibial tuberosity and patella on each model for simulating the kneeling and effect was analyzed under static condition. The maximum compressive stress of the CR, PS and HC tibial polyethylene insert and patellar polyethylene and PTT were calculated.

When the load was applied to base plate through the tibial tuberosity only, the maximum compressive stress of the CR, PS and HC tibial polyethylene insert were 2.7, 8.4 and 3.1 MPa, respectively. Those of CR, PS and HC patellar polyethylene were 0.04, 0.03 and 0.04 MPa, respectively. At the same loading condition, PTT of the CR, PS and HC were 4.2, 0.7 and 7.5 mm, respectively. Meanwhile, when the load was applied to base plate through the tibial tuberosity and patella, the maximum compressive stress of the CR, PS and HC tibial polyethylene insert were 0.2, 1.9 and 0.0 MPa, respectively. Those of the CR, PS and HC patellar polyethylene were 3.4, 2.7 and 3.4 MPa, respectively. At the same loading condition, PTT of the CR, PS and HC were 0.3, 0.2 and 0.4 mm, respectively.

Our study suggested that there was a similar trend between three different FE models regarding the patellar polyethylene stress under the two different loading conditions. The HC model had the highest PTT and the second highest compressive stress at the tibial polyethylene insert when the load was applied through tibial tuberosity only. This may generate the polyethylene insert wear while kneeling. Furthermore, the PS model had the high compressive stress of tibial polyethylene insert, especially on the posterior side of the post. Recently, there have been several reports concerning the breakage of post insert by over 60 degree of knee flexion after PS type of TKA. Additionally, the damages of anterior base of the post were noted during the revision surgery. Therefore, the repeated stress occurred onto the posterior side of the post of tibial polyethylene insert such as kneeling may lead to a fatal damage of PS type of TKA. Finally, the CR type of TKA may be the safest for the polyethylene insert when the TKA patients perform kneeling.

## P18

### IN VIVO ASSESSMENT OF HIP JOINT MECHANICS USING A MATHEMATICAL MODELING

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The objective of the study was to evaluate various bearing surfaces for THA using theoretical mechanics and data acquisition systems. Initially, a mathematical model of the human extremity was derived to determine in vivo bearing surface and soft-tissue (muscles and ligaments) forces. Input for this model was obtained using fluoroscopy to determine in vivo hip motions. Tri-axial accelerometers were attached to the greater trochanter and the pelvis to determine propagating frequencies across the hip joint and the transfer function. A sound sensor was attached to the hip joint to determine and correlate the incidence of hip separation.

Five subjects were initially evaluated in this study having press-fit THA with variable bearing surface interfaces. Patient selection was done by mobility, implant, and surgeon recommendation. All THA subjects were implanted by one surgeons and were judged clinically successful (Harris hip scores >90.0). The subjects were asked to perform a gait activity on a treadmill and on a force-plate under fluoroscopy surveillance. The two-dimensional fluoroscopic videos were converted into 3D using a computer automated model-fitting technique. The videos were evaluated for four stance phases and four 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 and used as input into the mathematical model. The force, acceleration and sound data was converted to the frequency domain and the frequency content was analyzed. The accelerometer and the sound transducer were used to examine bone frequencies and determine distinctive patterns during hip separation. A FFT analysis calculated the transfer function and other derived functions describing the dynamic behavior of the system.

Early results revealed that the maximum bearing surface forces ranged from 2.5 to 3.4 times body-weight. The force patterns for each subject were similar, but the magnitudes varied. Hip joint separation was demonstrated by subjects in this study. Results from this study may lead to a better understanding of in vivo mechanics of the hip joint. Propagating frequencies near bone and/or bone cement resonant frequencies may lead to bond degeneration in the hip joint. Further analysis is being conducted on more subjects before definitive conclusion can be made.

## P19

### **“OUR” ESTIMATES FOR ACCURACY AND PRECISION OF RADIOSTEREOMETRIC ANALYSIS IN A TOTAL HIP REPLACEMENT USING A PHANTOM MODEL**

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The use of Radiostereometric Analysis (RSA) continues to grow to evaluate implant migration and wear in THR with marker beads and conventional x-rays. It is vital to estimate the accuracy and precision of RSA prior to its use clinically. Astounding accuracies have been reported, to  $<86\mu\text{m}$  in some cases, from phantom studies with conservative simulated wear and migration  $<0.2\text{mm}$  in each direction. We present here an RSA phantom study to estimate accuracy and precision with larger distances.

A phantom setup was developed with a Sawbone model of a hemi-pelvis fitted with a popular THR. An XYZ positioning stage with  $1\mu\text{m}$  resolution micrometers was used to impart incremental displacements to the femoral stem relative to the cup and pelvis. Eight 0.8mm dia. Tantalum (Ta) beads, were inserted into the pelvis. Five (M4) nylon screws specially prepared with a 1mm dia. Ta marker on the threaded end were used to hold the cup to the hemi-pelvis. Another three 1mm dia. Ta beads were attached to the THR femoral stem. The relative motion between the markers on the femoral stem and those of the acetabular cup simulated penetration due to wear. The relative motion between the acetabular cup markers and those of the hemi-pelvis simulated socket migration. Forty two experiments were performed in total; each based on a pair of radiographs and involved a full RSA digitization and analysis using software from Biomedical RSA/Sweden.

The first 10 experiments involved no motion to estimate precision. 32 experiments followed, representing two consecutive analyses at each of 16 motion positions as follows: 0.2, 0.5, 1.0 & 2.0mm then back to 0.0mm in the medial direction, followed by the same increments in the superior direction, and then -0.5, -1.0, 0.0, 0.5, 1.0 & 0.0mm in the posterior direction. Simultaneous X-ray exposures were made at 120kV and 10mAs. For every pair of radiographs, the difference between the RSA measured values of position in a certain direction and the true values was calculated. The standard deviation was used to estimate precision. Accuracy was estimated from a 95% prediction interval (i.e. mean difference between each measurement and its true value  $\pm$  sd of the differences).

For Pelvis/Cup relative positions, where no actual motion was ever involved in all 42 cases, precision ranged from 0.013mm to 0.071mm. For Pelvis/Stem relative positions, precision ranged from 0.023 to 0.182mm, and for cup-stem from 0.029 to 0.230mm. Accuracy for Pelvis/Cup (no motion) ranged from  $\pm 0.026$  to  $\pm 0.139\text{mm}$ . Accuracy for Pelvis/Stem and Cup/Stem with no motion imposed ranged from  $\pm 0.055$  to  $\pm 0.536\text{mm}$ , and with translational motion it ranged from  $\pm 0.033$  to  $\pm 0.228\text{mm}$ .

The worst uncertainties were consistently along the anterior-posterior direction (depth into the radiographs). Our accuracy estimates were consistent with the 0.26-0.4mm reported in some other studies, but showed a 4, 3, 6, and 4-fold worse accuracy in Cup/Stem movement in the medial, superior, AP and resultant directions respectively compared to Bragdon et al, JOR, 2002. One reason may have been our larger motion ranges which represented realistic long term THR wear in-vivo with traditional implants. We also speculate whether the estimates in the other study were of a mean of a set of measurements, yet in this study we estimated the uncertainty in each measurement during a follow-up visit. We believe the latter is more relevant for clinical use.

We conclude that RSA precision is 0.23mm and its accuracy is  $\pm 0.5\text{mm}$ ; both of which are still very impressive. RSA is a very (if not the most) precise method, but its results should be viewed with these uncertainty figures in mind.



## **P20**

### **HIP SURGERIES BY MEANS OF 3D PREOPERATIVE PLANNING SYSTEM**

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Since 1989 we have been developing a computer system named “orthopedic workstation” to design a custom stem for each case. It was programmed for VAX station first and now it runs on Windows XP. As the system is oriented for designers and manufacturers, it can get canal geometries, design a custom stem optimized for each canal, create tool path and can optimize tool path too. But from the surgeon’s point of view, geometries of the bones and mutual relation between bones and/or prostheses are very important. To achieve these facilities, 3D preoperative planning system was developed separately. We have been using the system to solve many problems in hip surgeries. At present study, many kind of our usage of the 3D preoperative planning system are shown.

First the most important thing that a surgeon wants to know before surgery is the stability and sustainability of the prosthesis. Especially in Japan, as the main cause of the hip arthritis is developmental dysplastic hip (DDH), there are so many problems to be solved preoperatively. As for the stem selection, we always start from lateral flare cementless off-the-shelf stem which is based on our custom design concept. As it has very high proximal fit-and-fill, insertability and applicability can be examined preoperatively by the system. More than 90% of DDH cases can be covered with the OTS stem but cases with very severe deformity and cases after subtrochanteric osteotomy need to design custom stems.

DDH cases also often have larger anteversion angle. We have found that some of the cases with severe anteversion have developed capital and acetabular osteophytes to the posterior direction and reduced the mechanical anteversion for themselves. For those cases the adjusted anteversion angle should be restored after the surgery. If OTS stem cannot restore it, we should design a custom stem or use modular stem. We have done 9 cases of that situation so far.

DDH cases also have problems in acetabulum even they are Crowe’s type II or less, some special procedure will be required such as bone graft or usage of jumbo cup.

High-riding hips (Crowe’s type III or more) also have big problems. To obtain the anatomic hip center is very difficult because of the strong contracture and sciatic palsy. Subtrochanteric shortening osteotomy is often used then. But the method sacrifices the leg length equality. So we have selected 2 stage surgery with leg elongation. In the first stage, the soft part was released and the femoral neck was cut then leg elongating device was applied. The pin insertion into pelvis is very difficult. One reason is by the thin bone thickness, and another is the vessels inside. The system was utilized to determine the pin positions and the safe pin depth. The system also used to determine how to restore oblong or double sphere shape of acetabular defect.

Impingement prosthesis/bone vs. prosthesis/bone could also be analyzed by the system. The system has shown very valuable facility for hip surgery and more usage could be expected.

## P21

### THE “FRENCH PARADOX” EXPOSED: A FINITE ELEMENT ANALYSIS OF CEMENT PHILOSOPHY ON IMPLANT STABILITY AND CRACK FORMATION IN THE CEMENT MANTLE

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The success of the total hip arthroplasty depends on several surgical choices, such as the cementing technique and choice of the femoral component. Several studies have shown that a thin cement mantle should be avoided in order to delay failure of the femoral component. This evidence resulted in the generally accepted rule to select a nominal (‘undersized’) stem size that results in a cement mantle with a thickness of at least 2 mm.

In France, however, a surgical technique was developed that is in complete contradiction with this philosophy. The technique involves the implantation of the largest stem possible in order to fully occupy the intramedullary canal. To achieve this goal, a “canal-filling” stem is implanted line-to-line, which results in a thin cement mantle with multiple cement mantle defects. Surprisingly, excellent survival rates have been reported for total hip arthroplasties implanted with the line-to-line technique. This phenomenon of excellent clinical results obtained with two seemingly contradicting techniques has previously been referred to as the “French Paradox”.

In the current study, using finite element analysis, the underlying mechanism responsible for the “French Paradox” was investigated. The femoral implant size and the resulting cement mantle thickness were varied in models of a cemented Charnley-Kerboull hip arthroplasty. Furthermore, the quality of the bone supporting the cement mantle was varied. The effects of implant size and quality of bone supporting the cement mantle on fatigue crack formation and implant stability were simulated.

The number of cracks formed in the cement mantle was dependent on the implant size and the resulting cement mantle thickness, as well as on the type of bone that directly supported the cement. In general, the number of cracks increased with decreasing implant size. Cement crack formation was relatively high if the cement mantle was supported by trabecular bone only, while increasing the amount of cortical bone support to the cement mantle led to a decrease of the formation of fatigue cracks in the cement.

Models with canal-filling implants displayed a superior rotational stability compared to the models based on undersized stems, independently of the type of bone that supported the cement mantle. Increasing the amount of cortical bone supporting the cement mantle generally increased the rotational stability of the model.

The results of this study indicate that the so-called “French Paradox” may not be so paradoxical after all and can, at least partly, be explained by a careful mechanical analysis of the reconstructions that are obtained after using the various techniques. The fact that canal filling stems perform clinically so well is probably due to the relatively low cement stresses and an increased stability of the relatively large implants. However, perhaps the most important finding of this study is the demonstration of a clearly inferior mechanical reconstruction if the cement is not adequately pressurised.

This study provides an explanation for the French Paradox, and furthermore stresses the importance of adequate cement pressurisation.

## P22

### **TORSIONAL PROPERTIES OF FIVE TYPES OF HUMERAL STEMS: A BIOMECHANICAL ANALYSIS OF LOOSENING AND FAILURE CHARACTERISTICS**

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**Introduction:** The increasing popularity of uncemented humeral fixation in shoulder arthroplasty highlights the necessity for superior metadiaphyseal fixation characteristics in the respective humeral stems. Stable humeral fixation must be reconciled with the need to avoid proximal humeral fracture during stem insertion. We compared five different humeral stem designs in regards to torsional characteristics and safety of insertion (the production of humeral fracture).

**Materials:** Five different humeral stem morphologies were used for this study: minimized metaphyseal (MMin), minimized metaphyseal with lateral fin (MMinF), maximized metaphyseal (MMax), tapered block (TB), and the Foundation humeral stem (F) (Encore Medical Corp., Austin, TX). Stems were inserted via pilot holes into grade 15 PCF foam (Pacific Research Laboratories, Vashon, WA) and loaded at 1 degree per second with a servohydraulic dynamic testing system (Instron Corp., Canton, MA). Six testing sequences were attempted for each set of stems. Torque and angular displacement data were collected and a ramp waveform was conducted until each construct reached approximately 45 degrees of angular displacement. Mean load to displacement were calculated for each set of stems at 10 degrees and 45 degrees of angular displacement. The mode of failure was recorded in those cases where the foam block failed.

**Results:** The TB ( $p < .05$ ) stem performed best under torsional loads required to reach both 10 and 45 degrees of angular displacement (37N-m and 52 N-m, respectively). The MMax stem also performed well in the torsional load required to reach 45 degrees of angular displacement (43 N-m) but did not distinguish itself during load required to reach 10 degrees of angular displacement (19N-m). There were no significant differences between the MMin, MMinF, and F stems with respect to the load required to reach either 10 or 45 degrees of angular displacement. The TB stem had three instances where the foam block fractured during broaching. In the three instances where the TB foam blocks did not fracture during broaching, the foam blocks failed during torsional loading. The MMin and MMin F blocks also failed during torsional loading. There were no instances of foam block failure during the torsional loading of the MMax and F stems.

**Discussion:** Differing humeral stem designs displayed substantially different characteristics with respect to torsional resistance and the production of fractures during insertion and testing. Our data suggest that stems with the best torsional characteristics may also have the highest incidence of fracture during loading and insertion. When choosing a humeral stem morphology for shoulder arthroplasty, surgeons, designers, and bio-engineers must reconcile the need for strong humeral fixation with concerns regarding the production of humeral fractures during insertion.

## **P23**

### **“WITHIN ANY IMPORTANT ISSUE, THERE ARE ALWAYS ASPECTS NO ONE WISHES TO DISCUSS” FEMORAL COMPONENT FAILURE**

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#### **INTRODUCTION AND AIMS**

Complications still occur in THA. One of these complications continues to be femoral component failure. This subject needs more open discussion. The literature documents examples that unsupported stems will fail regardless of fixation, material, and design but has not recently addressed the risk due to increased patient activity.

#### **METHOD**

1,600 cementless stems were implanted since May 2001 for primary THA featuring a proximal modular neck design. All were implanted in three separate centers by six surgeons. Eight femoral component failures (locking pins) occurred between 2-4 years post-operatively. Each center used a different surgical approach (posterior, anterior muscle sparing, modified direct lateral) and a variety of cups and bearing surfaces.

All cases were reviewed as to surgical technique; implant size, patient activity and examination of retrieved device.

#### **RESULTS**

Eight locking pins were sheared resulting in torsional instability of the proximal modular junction.

Patient's complaint of an initial popping sound associated with a sense of hip instability was consistent in all. Pain was mild to moderate with initial x-ray appearance normal.

Surgical intervention found locking pin to be sheared with gross rotational instability of the proximal neck and black staining of tissue due to metal debris. Seven stems have been revised with standard length cementless stems of a variety of designs. All seven have gone on to full recovery. One patient is not a surgical candidate and is not experiencing any significant pain.

No material or fabrication defects were found. No surgical errors were found. Mechanical testing demonstrated safety levels to be beyond published activity loads. The culprit (in most cases) appears to be patient activity.

#### **CONCLUSIONS**

Historical published reports on torsion loading along with BMI have been underestimated. Increased patient activities are subjecting devices to unprecedented load levels.

Current patient activities generate excess of 95 ft pounds of torque. This review should be helpful in stem selection and increased warning guidelines as to patient activities.

## P24

### **PIN-ON-PLATE STUDIES TO ASSESS THE EFFECTS OF HEAT TREATMENT ON THE WEAR OF HIGH CARBON COBALT CHROME MOLYBDENUM ALLOY**

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**INTRODUCTION:** Cast Cobalt Chrome Molybdenum alloy (CoCrMo) may be heat treated to improve mechanical properties such as ductility and microporosity. These heat treatments alter the internal microstructure to reduce block carbide formation and increase homogeneity. The wear of as-cast high carbon CoCrMo alloy has been compared with a heat treated form of the same material containing fewer block carbides. Previous wear tests have reported little difference in wear rate between as-cast CoCrMo and heat treated CoCrMo (1, 2).

**MATERIALS AND METHODS:** Specimens of high carbon (0.266 wt%) CoCrMo alloy either in the as-cast condition or heat treated were tested in a 4 station pin-on-plate machine with reciprocating and rotational motion. A soak control was used in each test to correct for weight fluctuations not caused by wear. All pins and plates tested were manufactured by SMITH AND NEPHEW ORTHOPAEDICS LTD . Each test was carried out under the same conditions with a stroke length of 18mm and a force of 40N on each pin during testing. The samples were submerged in 25% bovine calf serum at 37°C which was replaced every 250,000 cycles. The wear was assessed gravimetrically throughout the test and the surface of the pins and plates was investigated using a non-contacting profilometer at the beginning and end of each test. The as-cast test was taken to 2.5 million cycles and the heat treated test to 3 million.

**RESULTS:** The as-cast CoCrMo gave an average wear factor of  $1.670 \times 10^{-6}$  mm<sup>3</sup>/Nm and the heat treated CoCrMo gave a wear factor of  $2.406 \times 10^{-6}$  mm<sup>3</sup>/Nm. A statistical test (ANOVA) was carried out on the values and it was found that these two tests are significantly different ( $p < 0.05$ ). These results show that the as-cast alloy performed better than the heat treated alloy.

**DISCUSSION:** The thermally treated CoCrMo wore 1.44 times more than the as-cast CoCrMo. Carbides could be seen protruding from the as-cast plates surface when analysed at the conclusion of the test whereas the thermally treated plates showed no carbides when analysed. Both tests showed no signs of running in and both sets of results showed linear wear.

**CONCLUSION:** The well established as-cast CoCrMo has performed better than the thermally treated modified morphology CoCrMo by giving a lower wear factor. Both materials showed a linear wear pattern and therefore no running in. It would appear that the structural differences between the materials cause the different wear factors.

The authors would like to thank SMITH & NEPHEW ORTHOPAEDICS LTD for funding this research.

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## **P25**

### **ALIGNMENT CHANGE OF THE LOWER EXTREMITY AFTER TOTAL HIP ARTHROPLASTY**

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#### **INTRODUCTION**

It is known that osteoarthritis (OA) of the hip affects the lower extremity alignment on both ipsi- and contralateral side. The purpose of this study was to investigate the change of the lower extremity alignment after total hip arthroplasty (THA).

#### **PATIENTS AND METHODS**

We evaluated 70 patients (140 limbs) who underwent unilateral THA with normal contralateral hips. The minimum follow-up period was 2 years. Postoperative limb lengthening more than 20 mm of the affected side was divided into group A (50 limbs) and the lengthening less than 20 mm was in group B (90 limbs). The percentage of mechanical axis (%MA) was measured on the standing radiographs of both ipsi- and contralateral sides and also the knee was evaluated by the Kellgren and Lawrence classification to determine the OA development.

#### **RESULTS**

On ipsilateral side, %MA decreased from 56.6% to 46.2% in group A ( $p<0.001$ ) whereas it decreased from 43.2% to 36.8% in group B ( $p<0.001$ ). On contralateral side, %MA increased from 38.9% to 43.7% ( $p<0.05$ ) in group A but no significant change was found in group B. The assessment of knee OA showed that 42% knees on ipsilateral side and 16% knees on contralateral side deteriorated in group B, whereas those percentages decreased to 20% on ipsilateral side and 12% on contralateral side in group A.

#### **CONCLUSION**

Limb lengthening more than 20 mm can correct the malalignment of genu valgus (coxitis knee) which is due to the leg length discrepancy and prevent the knee joint from OA progression.

## P26

### THE EXPERIENCE OF NAVIGATED MIS TKA WITH ORTHOPILOT

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**INTRODUCTION** Recently the kinematic computer-assisted navigation technology has already shown improved alignment results in TKA. OrthoPilot navigated TKA software provides the ability of additional navigation of soft tissue balancing to allow dependent cut technique. These are essential to the immediate and long-term clinical success. Together with the usage of ultra-congruent E-motion prosthesis, which is permitted to use only with OrthoPilot, its technology is very promising. Additionally, the technique of minimum-invasive-surgery (MIS) is perceived to reduce soft tissue trauma. However, the reduced exposure during surgery bares the risk of component mal-positioning. Smaller scars should not be considered as the main purpose of the so-called MIS, as the beneficial effect and the natural consequence of a more conservative technique are also important; sparing soft tissue such as the quadriceps tendon, the extensor mechanism and the supra-patellar pouch as well as nervous tissue and vascular supply. Therefore we have combined MIS and navigation. If these will be achieved sufficiently, TKA will be lead to good results; straight mechanical leg axis, little deviations from optimum for each single femoral and tibial axis, perfect collateral ligament balancing, and optimal range of motion. The purpose of this paper is to evaluate the usefulness of the navigated MIS TKA comparing to the conventional navigated TKA, although we have limited number of cases.

**MATERIALS AND METHODS** Conventional navigated TKA has been performed from October 2004 at our institute. The number of cases was 26 knees (male 5cases, female 21 cases) until August 2005. Navigated MIS TKA was performed in 15 cases up to the present date. Patients' average age in the conventional group was 74 years (range, 62-90 years old) and in the MIS group was 71 years (range, 60-78 years old). The average hospitalization period in the conventional group was 35 days and 33 days in the MIS group. Primary endpoint was KS score difference between pre-operation and at the time of discharge. The second endpoint was the time it took to achieve the SLR and the disappearance of the extension lag. The third endpoint was visual analogue scale (VAS) of pain one week after the surgery. The fourth endpoint was surgical time and blood loss after surgery.

**RESULTS** There was no significant difference in the KS score , the age and the hospitalization period between the two groups. However, there was a significant difference between the time to achieve the SLR, the disappearance of the extension lag and in the VAS about pain. MIS group achieved the SLR and the disappearance of the extension lag sooner than the conventional group. The average surgical time in the MIS group was 15 minutes longer than in the conventional group. But the average blood loss was less in the conventional group.

**CONCLUSION** MIS TKA will provide painless situation to the patients who do not have much damages of their extensor mechanism. Patients tend to prefer to receive the TKA on the opposite side with the same procedure.

## **P27**

### **SHORT-TERM RESULTS OF TOTAL ELBOW ARTHROPLASTY IN RHEUMATOID ARTHRITIS**

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#### **OBJECTIVE**

To present the short -term results of total elbow arthroplasty in rheumatoid arthritis patients.

#### **METHODS**

From November 2002,till date, fifteen elbows in thirteen patients who had rheumatoid arthritis underwent primary total elbow arthroplasty. The mean age of the patients was 64.4 years. The prosthesis used was FINE ELBOW PROSTHESIS (Nakashima ,Okayama,Japan).

All patients were assessed by the elbow scoring system of the Japanese Orthopedic Association (JOA score).

#### **RESULTS**

The J.O.A score improved from 43.9(pre-operative) to 85.9 ( post-operative) at the final examination.

There was significant improvement in range of motion after the surgery. The most prominent observation was reduction of elbow pain, and improvement of elbow extension.

Radiological follow-up showed no evidence of loosening of the components.

Total elbow arthroplasty with FINE ELBOW PROSTHESIS in rheumatoid arthritis patients can lead to improvement in range of motion,function and pain.



## **P28**

### **CLINICAL RESULT OF CEMENTED MOVABLE CALCAR STEMS**

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Proponents of collar and collarless stem's were well documented.

However, few of them described movable calcar stem's while walking in the past literatures.

Therefore, we developed clinical trial of movable calcar stem's which we have introduced through Link Germany in early 1989. Even though 10~15 years post operative results were satisfied. Of the 82 patients, 90% were free from pain or had no more than occasional dislocation discomfort.

Radiographically, none of them resulted proximal medial neck resorption under the calcar.

On the other hand, there were no wear debris secondly to micromotion between the collar and cement as well as the collar and the calcar. We confirmed that RSA (Roentgen, Stereophotogrammetric Analysis) is far better for detection of the stem alignment compared with 3D. FEM, analysis.

## P29

### STATISTICAL APPROACH TO CORRECT PELVIC INCLINATION USING ESTIMATED THICKNESS OF SOFT TISSUE

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Several navigation systems have been used to secure the correct alignment of the implant in THA. These navigation systems may be classified as image based and non image based navigation systems. Some of the non image based systems use anatomical landmarks of pelvis for determining the anterior pelvic plane to obtain the orientation of the acetabular cup. However, there is difference between the measured and actual pelvic plane due to the measurement error by the thick soft tissue at the anatomical landmarks. The object of this work is to establish a compensation method from the analysis of the soft tissue's thickness and elasticity as well as the patients' B.M.I. and age.

The pelvic inclination is defined as the rotation of the anterior pelvic plane around a transverse axis with respect to the frontal plane. The positive inclination of pelvis means that the pelvic plane is tilted forward. We employed a customized inclinometer made of a T-bar shaped gauge and goniometer to measure the pelvic inclination in lying and standing positions for 33 volunteers. In order to obtain the actual thickness of the soft tissue on the pubic bone, a portable ultrasound imaging system (Sonoace PICO, Medison, South Korea) and linear probe (HL5-9ED, MEDISON, South Korea) were used. Simultaneously, the compressive force was measured with a S-beam load cell (BONGSHIN LOADCELL, South Korea) during sounding. In addition, we used a 3D position measurement device (MicroScribe, IMMERSION Inc.) with the load cell to find the correlation between the reaction force and thickness.

The mean inclinations of the measured plane in standing and lying were  $-8.3^\circ$  and  $-5.5^\circ$  respectively. In average, the thickness of the soft tissue was decreased by  $41.2 \pm 10.9\%$  amounting the the compression of  $9.5 \pm 4\text{mm}$  under the load. We are developing a calibrating formula to reduce the error in estimating the soft tissue thickness without using devices such as ultrasonic probe.

## **P30**

### **IMPROVED MECHANICAL ORIENTATOR FOR ACETABULA CUP ALIGNMENT IN THA**

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Proper acetabular cup orientation is a major factor affecting ROM and longevity of the inserted hip implants. Sometimes securing correct orientation of the cup might be difficult during an operation because of difficulty in identifying the pelvic plane. There are many helpful surgical techniques and devices for surgeons to obtain an accurate orientation of the acetabular component intra-operatively. A-frame attached to an inserter serves as a representative example for positioning the cup properly. However, alignment by A-frame can be wrong when the patient's pelvic plane is inclined to the operating table. In the other hand, those navigation systems using computers and position measurement devices provide an accurate position and alignment in real-time. But these navigation systems require expensive measurement devices additionally, which cause extra cost and time. In this paper, a mechanical-orientator which requires less cost and effort is proposed for assisting the alignment of the acetabular cup in THA.

A mechanical-orientator consists of a pelvic marker, T-bar shaped pelvic plane gauge, orthogonal frames and 2 goniometers. The orientator employed the radiographic definition of cup angles for the alignment of the acetabular cup. The pelvic marker is firmly attached to the pelvis with 2 pins and the T-bar shaped gauge is placed on top of the three anatomical landmarks to locate the pelvic plane. Both pelvic marker and T-bar shaped gauge have orthogonal frames to align the pelvic marker with the pelvic plane. After the alignment of the orthogonal frame of the goniometer attached to the orientator to the pelvic marker, this orientator can guide the orientation of the acetabular cup by the goniometer. The repeatability and angular accuracy of the orientator is evaluated by independent measurement devices (OPTOTRAK3020, NDI.)

The orientations by the mechanical orientator were compared with the one obtained by OPTOTRAK. The mean errors and maximum errors in abduction and anteversion were  $0.45^\circ$ ,  $-0.77^\circ$ ,  $3.45^\circ$  and  $-2^\circ$  respectively.

This mechanical orientator has both accuracy and cost-effectiveness because only simple mechanical devices are used. In vivo test, we confirmed that the feasibility of the orientator and the clinical results shall be presented in future work.

## **P31**

### **EXPERIENCE IN THE USE OF GENESIS MBK**

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#### **OBJECTIVE**

We reviewed short-term results of performance of GENESIS Mobile Bearings.

#### **MATERIALS AND METHODS**

Data was obtained from 49 knees in 49 patients undergoing surgery with GENESIS Mobile Bearings. There were nine men and forty women patients, with the mean age of 72 years ( 47 to 84 ). The diagnosis of primary disease was osteoarthritis(OA) in 38 patients, and rheumatoid arthritis(RA) in 11. The procedures for fixation employed were cemented in 14 knees, and cementless in 31, and hybrid in 4.

All the patients were treated with PCL retained , the use of fixation pegs on AP migration of a tibial insert in 12 knees, non-use in 37 knees, replacement of a patella in 46 knees, and non-replacement in 3.

#### **RESULTS**

We examined clinical scores (the knee and functional scores before and after surgery) , knee range of motion before and after surgery, PF joint (an inclination angle of the patella and lateral shift), postoperative radiographs (setting angles for each component of the femur, tibia, and patella. and fluoroscopic views).

Good short-term clinical results of the performance of prosthetic knees with GENESIS Mobile Bearings were obtained in terms of knee scores, functional scores, setting angle on radiographs, alignment, fluoroscopic views and the like.

#### **CONCLUSION**

We reviewed the short-term clinical results of performance for GENESIS Mobile Bearings. Our review revealed clinical scores and a radiographic analysis as good, which has constituted a basis for long-term results of the performance of MBK.

## P32

### PROFILE OF ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE IN NEW AND RETRIEVED ACETABULAR CUPS CHARACTERIZED BY CONFOCAL RAMAN SPECTROSCOPY

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During the past four decades, ultra-high weight polyethylene (UHMWPE) has been the most commonly used material for orthopaedic application in total hip replacement (THR). A typical hip implant consists of a metallic or a ceramic femoral head that articulates against a UHMWPE acetabular cup. Recently, the prosthesis design and fixation methods have been significantly improved and very low traction and wear rates could be obtained. However, the generation of UHMWPE wear particle yet represents the most critical concern for long-term implantation of THR. In order to decrease polyethylene (PE) wear, gamma ( $\gamma$ )-irradiation is often used to sterilize for medical use before implantation of PE components in human body. When PE is irradiated by gamma rays, the main effect is to generate free radicals through hemolytic bond cleavage. The main consequence of this physicochemical process is that the free radicals can lead to cross-linking in the polymeric structure. However, in the presence of oxygen, free-radicals may oxidize as well. This is indeed the main shortcoming in using  $\gamma$ -irradiation, because this phenomenon gives serious problems to both wear and mechanical resistance of the joint. Both chain scission and oxidation processes have significant effect on the structural integrity of the polymer: (i) as the long chains break in the polymeric structure, the resultant shorter chains become capable to pack together more easily, leading to higher crystallinity and density; and, (ii) as the oxidative degradation proceeds, stiffening of the molecular chains occurs, which can lead to hardening but also to significant embrittlement of the polymeric structure. Despite the importance of the as-manufactured UHMWPE structure and of its evolution *in vivo*, specific trends in microstructural development and related mechanical behavior of UHMWPE upon changing the conditions for  $\gamma$ -irradiation have been somewhat only empirically characterized and classified. We study new and retrieved UHMWPE acetabular cups using a previously optimized confocal Raman spectroscopic technique. We attempt here to evaluate the degree of crystallinity, orthorhombic, amorphous phases and the state of oxidation of new and retrieved UHMWPE acetabular cups as a function of the *in-depth* abscissa. Extensive mapping confocal Raman spectroscopy enables one to statistically characterize the state of both UHMWPE surface and subsurface with a non-destructive, high-resolution, three-dimensional spectroscopic procedure.

## **P33**

### **IN VIVO MECHANICS COMPARISON FOR VARIOUS LUMBAR SPINE CONDITIONS**

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Recently, spinal disk replacement is becoming a topic of great interest, most notably, whether it offers an advantage over spinal fusion. Before the orthopaedic industry ventures too far into this area, one might want to consider and further understand the in vivo mechanics of the normal and disc degenerated lumbar spine. . Therefore, the objective of this study was to determine the in vivo kinematics and kinetics of the lumbar spine using fluoroscopy and mathematical modeling techniques.. Initially, ten subjects (5 Normal and 5 Degenerative) were asked to perform normal lumbar flexion/extension activities under fluoroscopic surveillance. The derived in vivo kinematics were then entered into a simplified two-dimensional (2D) and complicated, three-dimensional (3D) mathematical model of the lumbar spine segments. . The kinematics of the two groups demonstrated significant differences, in both 3D and in 2D. In the 2D analysis, the bearing surface forces were greater for the normal spine than the degenerative spine, mainly due to the decreased motion between the segments. The normal spine experienced 13.5 degrees of L4-L5 flexion, while the degenerative spine only achieved 6.0 degrees. Further analyses, in 3D, revealed significantly greater out-of-plane rotation for the degenerative spine, thus leading to higher out-of-plane forces and higher resultant forces than the normal spine. During this activity, the degenerative lumbar spine subjects experienced greater than 6.2 degrees of out-of-plane rotation. In our future analyses, we will investigate the effects of these abnormal conditions to the adjacent levels and the soft-tissues.

## **P34**

### **MID TO LONG TERM FOLLOW-UP RESULTS OF FEMORAL REVISION TOTAL HIP ARTHROPLASTY USING WAGNER STEM**

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#### **PURPOSE**

To analyze the result of 5-15 year (mean, 8 years 1 months) follow-up of the femoral revision THA using Wagner revision stem.

#### **MATERIALS AND METHODS**

Of 79 patients who underwent revision THA at our institution between Mar 1991 and Jan 2000 with this stem, 64 aseptic loosening patients (69 hips, 44 males and 20 females) with a minimum of 5-year follow-up were enrolled in the study. During the follow-up, clinical and radiographic results and postoperative complications were evaluated.

#### **RESULTS**

Harris hip score improved from 48.6 to 91.2 points, postoperatively. There were 3 re-revisions due to a failed stem fixation and aseptic loosening. The Kaplan-Meier survivorship analysis, with failure defined as a removal of the Wagner stem, revealed a 97.1% survival chance at 12 year follow-up. Besides the revisions, 66 hips showed no residual symptoms postoperatively; however, in 1 case, definite limping with thigh pain was noted. Radiographical findings included subsidence of the implant (5 cases, 7.5%, all less than 10mm), calcar femoral atrophy (4 cases, 6.0%), stress shielding (4 cases, 6.0%), heterotopic ossification (5 cases, 7.5%). Postoperatively, peroneal nerve palsy was noted in 2 cases but they recovered completely within the following one year without any specific treatment.

#### **CONCLUSION**

We were able to obtain a stable fixation and quite satisfactory results in our revision cases using Wagner revision stem.

**KEY WORDS:** Wagner revision stem, Aseptic loosening, Revision THA.

## P35

### COMPARISON OF KNEE MECHANICS FOR THE NORMAL VARUS, AND VALGUS KNEES

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Varus and valgus knee deformity influences not only knee kinematics, but it is hypothesized that the loads acting at the knee joint are also altered. Therefore the objective of this study was to develop a mathematical model of the human knee to determine the bearing surface knee and muscle forces resulting from varus/valgus deformity.

A parametric, inverse dynamics, mathematical (computational) model of the lower limb was derived and was used to predict and compare knee mechanics for variable knee conditions during a deep knee bend (DKB). The ground reaction force was measured using force plate and used as an input force. In-vivo kinematics data were determined using fluoroscopy and a three dimensional model-fitting technique. Three rotations of the femur relative to the tibia were specified. The translation rotation of the patella relative to the femur was measured in the sagittal plane only. The wrapping of the patellar ligament around the tibia and the wrapping of the quadriceps around the femur were included. The force applied by the patella on the femur, as well as force of the quadriceps and the patellar ligament were modeled as a three-force system and modeled at their attachment sites. The forces in the anterior and posterior cruciate ligaments (ACL and PCL), and medial and lateral collateral ligaments (MCL and LCL) were found to be governed by the force-strain relationship.

The patellofemoral force, predicted under severe deformity, was found to reach 6.5 times body weight (xBW). The quadriceps muscle and the patellar ligament forces, under these conditions experienced a maximum amount of 6.2 and 4.1 xBW, respectively. The maximum femorotibial force, derived at the bearing surface interface was 4.9 xBW. Ligament forces were all below the value of 0.6 xBW. The pattern of the forces within the ACL and PCL clearly demonstrated the synergism of these ligaments. Comparison of the results obtained for the varus and valgus models with the normal knee revealed distinct differences in the coronal plane. The medial-lateral force acting within the normal knee was predicted to be 50 N, but for the varus knee the force ranged from 80 to 150 N and the valgus knee experienced a maximum force of 264 N. The moment required to balance the tibia in the coronal plane revealed the most significant difference between healthy and malaligned knees. While for the normal knee the moment value was small and oscillated near zero (+/- 2.8 Nm), the deformed knees experienced -56.52 Nm and 61.08 Nm for valgus and varus knee models, respectively.

The results in this study revealed that there is not significant difference between malaligned and normal knee forces acting in the sagittal plane. The results for the malaligned knees revealed significantly greater moments, which the soft tissues need to balance, compared to the normal knee. These results may explain the pathomechanism of the varus and valgus knee diseases, since the normal knee experiences significantly lesser moments, compared to the varus and valgus knees.



## **P36**

### **POROUS TANTALUM IN HIP AND KNEE ARTHROPLASTY**

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Trabecular metal, a new low modulus metal with a characteristic appearance similar to cancellous bone, is currently available for use in primary and revision total hip and knee arthroplasty. Tantalum is a transition metal, which in its bulk form has shown excellent biocompatibility and is safe to use *in vivo* as evidenced by its current application in pacemaker electrodes, cranioplasty plates, and as radiopaque markers. The open-cell structure of repeating dodecahedrons is produced via carbon vapor deposition of commercially pure tantalum onto a carbon-fiber scaffolding. Current designs for orthopaedic implants maintain a high volumetric porosity (70-80%), low modulus of elasticity (3 MPa), and high frictional characteristics making this metal conducive to biologic fixation. Its more bioactive nature and in-growth properties have led to its use in primary as well as revision hip and knee components with good early clinical results reported. In the setting of revision arthroplasty, it has been utilized as a structural bone graft substitute. Formation of a bone-like apatite coating *in vivo* affords strong fibrous in-growth properties and allows for substantial soft tissue attachment with the potential for use in cases such as mega-prostheses and patella salvage. Although porous tantalum is in its early stages of evolution, the initial clinical data and basic science studies support its use as an alternative to traditional orthopaedic implant materials. The following represents a review of its unique biomaterial properties and applications in total hip and knee arthroplasty.

## **P37**

### **THE EFFECT OF METAL STAINING ON CERAMIC ON CERAMIC HIP SIMULATION WEAR**

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Impingement of a ceramic femoral head against metal can result in surface damage to the ceramic as well as transfer of metal to the surface of the ceramic. These effects have been postulated to lead to increased ceramic wear.

We present the results of a ceramic-on-ceramic hip simulation study in which the wear rates of three groups of components were compared. These groups were new, never-implanted components, retrieved components with metal staining and new components that had been stained by in vitro ion implantation methods. The retrieved heads were run against new ceramic liners. The ion implanted metals were of the same composition as found from the retrieved components.

After 5 million cycles on a Shore Western Hip Simulator, there was no measurable wear of the heads or liners for both the pristine and in vitro stained, never-implanted components. The two retrieved, stained heads had wear rates of 0 and 1.0 mg/million cycles. The corresponding wear of the liners was .08 and 2.9 mg/million cycles.

These results indicate that it is the surface roughening and not the metal that cause increased ceramic wear. The wear of the retrieved liners was higher than that of the never-implanted components. However, these elevated wear rates are very low and on the order of the wear rates reported for highly cross-linked polyethylene.

## P38

### COMPARISON OF HIP RESURFACING WITH BUFFERED FIXATION TO CEMENTED FIXATION: A FINITE ELEMENT ANALYSIS

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Recently, as wear resistant bearing technology has been developed, hip resurfacing also gets the renewed interests. However, aseptic loosening, osteolysis, and osteonecrosis still occur demanding the fixation between implant and bone to be improved. In this study, we assumed that the cement-bone interface tensile stress of current cemented fixation might cause the debonding in the bone-cement interface and lead to the failure. Consequently, we propose a new concept of implant fixation that uses a buffer instead of the cement in order to apply the physiologically favorable stress to the bone. In our proposed method, the buffer and implant are tapered. Then, this buffer is inserted into the space between femoral head and implant. When the body weight is applied to the implant, we assume that they were fixed by taper-lock mechanism ensuring the initial stability and osseointegration for the implant.

At first, we made following FE models describing proposed buffered implants including implant, buffer and femoral head. The models had three different thicknesses (0.5mm, 1mm, 2mm) and three different taper angle (3°, 4°, 5°) to find the influence of the buffer shape. We used PEEK as a buffer material. We modeled all contact surfaces of femoral head, buffer and implants as Coulomb friction to simulate the situation immediately after the operation. The friction coefficient was assumed to be 0.18 for the buffer-implant interface polished metal surface, and 0.6 for the buffer-bone interface to simulate the roughened buffer surface. Also, we made FE models of the implant with cemented fixation. In the cemented implants, bone-cement interface was assumed to be perfectly bonded. We compared the contact stresses in the femoral head between the buffered implant FE models and the cemented implant FE models.

In the case of using buffered implant, the results of FEA studies showed that the buffer and femoral cup were well fixed by taper-lock mechanism and the buffer surface transferred mostly compressive stress in every interface surface. Especially the tensile stress of the bone-buffer interface in medial region was reduced significantly comparing with the cemented fixation method which showed broad tensile stress regions.

Novel fixation method of implant in hip resurfacing produces mostly compressive stress in every bone-implant interface. It may improve the bone-implant interface to osseointegrate so the osteolysis and aseptic loosening rate in hip resurfacing will be decreased.

## P39

### TREATMENT OF FICAT STAGE II & III OSTEONECROSIS WITH FEMORAL HEAD RESURFACING HEMIARTHROPLASTY IN THE YOUNGER PATIENT: A PROSPECTIVE, SINGLE SURGEON REPORT ON AVERAGE 2 YEAR FOLLOW-UP

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**Introduction:** Osteonecrosis (ON) of the hip can be devastating, oftentimes severely impairing young patients' physical function and quality of life. Traditional treatment via total hip arthroplasty (THA) has resulted in suboptimal results due to the younger, more active patient demographic which generally characterizes the disease. Other less aggressive surgical treatments have met unpredictable results also. Preservation of bone stock and avoidance of acetabular component placement can be achieved by treatment with femoral head resurfacing hemiarthroplasty (FHRH).

**Materials & Methods:** Twenty-four consecutive FHRH's (Conserve Hip, Wright Medical Technology, Arlington, TN) were performed in 21 patients (11 males/10 females; mean age of 42, range, 20-57). Of the 24 hips operated on, 3 were diagnosed with Ficat Stage II osteonecrosis, while 21 were found to exhibit Ficat Stage III disease. No patients were lost to follow-up. Clinical outcomes were prospectively assessed via the WOMAC and Harris Hip Society Scores and compared to baseline. Kaplan-Meier survivorship and Student's t-test was performed by GraphPad Prism 4 software (GraphPad Software Inc., San Diego, CA).

**Results:** Mean time of follow up was 30 months. Three hips were converted to THA's due to persistent complaints of pain, and not due to femoral neck fracture or component loosening.. Kaplan-Meier survivorship analysis reported 94% survivorship at 30 months (95% CI) using conversion to THA as the primary endpoint. At time of mean follow-up preoperative WOMAC stiffness and Harris Hip Scores significantly improved from  $42 \pm 22$  and  $46 \pm 15$  to  $72 \pm 16$  ( $p < 0.05$ ) and  $73 \pm 17$  ( $p = 0.003$ ), respectively.

**Discussion & Conclusion:** The significant short term improvements observed in both hip function and stiffness at 2 years after FHRH are encouraging. Similarly, 94% survivorship at 30 months exhibits good initial results for the procedure despite complicated medical histories of this patient cohort. Within the patient group, complicated comorbidities include, but is not limited to diagnoses of AIDS, lupus, psychiatric diagnoses, end-stage renal disease (3 patients with renal transplants), ischemic heart disease (1 patient with heart transplant), chronic pancreatitis, breast and intestinal cancer, Cryptococcus meningitis, and polysubstance abuse. We believe aggressive, early treatment of painful or nearly collapsed femoral heads with osteonecrosis can be readily achieved via FHRH, even if to delay an eventual THA. Preservation of bone stock and minimizing acetabular disruption, therefore, eases the conversion surgery when needed. Continued clinical and radiographic follow-up is necessary in order to elucidate the longer-term efficacy of the procedure.

## P40

### RELIABILITY OF LEG-LENGTH MEASUREMENT USING A SIMPLE DEVICE DURING TOTAL HIP ARTHROPLASTY TO PREVENT POST-OPERATIVE LENGTH DISCREPANCY

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Limb length inequality after total hip arthroplasty (THA) may lead to certain complications such as limp, low back pain and aseptic loosening. To prevent this matter, we used the PCA limb lengthening gauge (Stryker, Mahwah, NJ) to estimate intra-operative limb length change. The gauge simply consists of a ruler and two pins. The pins of original device are the same, but we replaced the pin for the acetabulum to a threaded pin and installed a stopper in order to prevent penetration of the pin to the pelvic cavity. In this study, we evaluate its accuracy.

Forty-three THAs were performed between August 2002 and May 2005 by a single surgeon (TK), using this gauge during the operation. THAs were performed on the lateral position and with a posterolateral approach. The pins were inserted to the positions on the lengthening axis before the femoral head was dislocated. The positions and insertion routes were (i) percutaneous and 2 cm above the joint on the acetabulum side, and (ii) the most lateral point of the great trochanter under the direct observation on the femoral side. The gauge was set between the pins and the distance was recorded 3 times during the surgery, i.e., before the dislocation, after inserting a tryout-prosthesis, and after setting a real prosthesis. The gauge and the pin on the femoral side were removed during surgical operation. According to the distance measured after inserting a tryout-prosthesis, the volume of neck osteotomy and the neck length were adjusted. The difference between the length before the femoral head dislocation (first measurement) and the length after setting the real prosthesis (third measurement) was determined as the intra-operative leg-lengthening.

Preoperative limb length inequality measured from standard antero-posterior radiographs was 9.8 mm (0-35mm) on average. We compared the limb length change made on pre-operative and post-operative radiographs to the intra-operative measurements using the gauge, and evaluated correlation between the values.

The mean value of limb length changes based on pre-operative and post-operative radiographic measurements was 9.7mm (0-21mm), and the mean value of intra-operative measurements was 10.4mm (0-20mm). Pearson's correlation coefficient between the two values was found to be 0.89 ( $p < 0.001$ ). A significant correlation between radiographic and intra-operative measurements was observed. Post-operative leg length inequality measured from radiographs was 3.1 mm (0-19mm) on average. The mean error calculated as differences between the radiographic measurements and the intra-operative measurements in absolute value was 2.1mm (0-7mm).

This method was very simple and easy, but extremely accurate to manage limb length change during THA. Although the PCA limb length gauge is a rather old instrument, its effectiveness in surgery should not be overlooked.

## **P41**

### **PELVIC TILT AFFECTS THE ANTEVERSION ANGLE OF ACETABULA ON CT**

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#### **INTRODUCTION**

For Total Hip Arthroplasty (THA), information obtained from CT data is very useful for preoperative evaluation of acetabular deformity, and postoperative evaluation of acetabular component positioning. Generally, axial view images are used for the evaluation of acetabular anteversion angle though these images are usually not taken considering pelvic tilt. In this study, we investigate the effect of pelvic tilt on the measurement of the acetabular anteversion angle using CT axial view images.

#### **MATERIALS AND METHODS**

First, we obtained axial CT data of sawbone. The sawbone was fixed in the same position with tilt adjusted superiorly or inferiorly with respect to the center of the acetabulum to simulate pelvic tilt, then acetabular anteversion angle was measured at each angle of incidence.

We also evaluated 16 cases in 18 hips with avascular necrosis of the femoral head up to Stage B and primary Osteoarthritis of hip without acetabular dysplasia of the contralateral side, as we could obtain CT data in DICOM format preoperatively for these cases. Since pelvic tilt was different for each case, we established a reference plane which connected 4 points: both superior anterior iliac crests and both pubic tubercles. The slices which crossed this reference plane at right angles and the slices which were tilted to the plane by 10 degrees were reconstructed with Multi Planar Reconstruction, and acetabular anteversion angle was measured.

#### **CONCLUSION**

The study with sawbone showed an acetabular anteversion angle of 18.6 degrees with the angle perpendicular to the reference plane (0 degree), 6.8 degree with an angle of 10 degrees superior (equivalent to an anterior tilt of 10 degree), 21.6 degrees with an angle of 10 degrees inferior (equivalent to a posterior tilt of 10 degrees) and 24.8 degrees with an angle of 20 degrees inferior (equivalent to posterior tilt 20 degrees).

The study with clinical cases showed an average acetabular anteversion angle of 18.3 degrees with 0 degrees of pelvic tilt, 12.6 degrees with a tilt of 10 degrees superior, 25.1 degrees with a tilt of 10 degrees inferior and 29.0 degrees with a tilt of 20 degrees inferior. Similar to the study with sawbone, anteversion angle increased as pelvic posterior tilt was increased.

#### **DISCUSSION**

Pelvic tilt varies by each patient, and, as this study show, pelvic tilt affects acetabular anteversion measurements. It is impossible, therefore, to evaluate acetabular anteversion angle simply by using CT data of axial images and comparing individual differences. Recently we have seen more elderly patients with increased pelvic posterior tilt as candidates for total hip arthroplasty, so we must consider pelvic tilt when evaluating acetabular anteversion angle using CT data.

## P42

### IN VIVO COMPARISON OF ACL DEFICIENT AND NORMAL KNEE KINEMATICS DURING A DEEP KNEE BEND AND GAIT

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The goal of this study was to compare the in vivo knee kinematics for the Anterior Cruciate Ligament Deficient (ACLD) knee and the normal contra lateral knee. While under fluoroscopic surveillance, four subjects performed a weight bearing Deep Knee Bend (DKB) to maximum flexion and gait, using their ACLD and normal knee. During DKB, on average, the ACLD knee experienced -15.1 mm (Standard Deviation= 10.2) and -5.1 mm (SD=3.0) of lateral and medial condyle posterior femoral rollback (PFR), respectively, and 10.2° (SD=13.1) of axial rotation. The normal knee experienced -14.2 mm (SD=9.1) of PFR and -6.2 mm (SD=3.6) of PFR on the lateral and medial sides, respectively, and 9.9° (SD=8.1) of axial rotation. During gait, on average, from heel strike to toe off, the ACLD knee experienced -1.9 mm (SD= 4.4) of PFR and -2.2 mm (SD=6.8) of lateral and medial condyle PFR, respectively, and -0.8° (SD= 13.37) of axial rotation. During gait, the normal knee demonstrated -1.7 mm (SD=4.5) and -3.7 mm (SD=3.0) of lateral and medial PFR, respectively, and -2.4° (SD=7.7) of axial rotation. Although the average motion patterns were similar for both knees, two subjects experienced minimal axial rotation for their ACLD knee and all ACLD knees remained more posterior in contact position than the normal knees. Therefore, it can be assumed that the ACL plays a significant role in axial rotation and anteriorisation of lateral condyle contact position during both gait and a deep knee bend, especially at full extension.

## P43

### A NOVEL TOOL FOR FEMORAL IMPLANT PLANNING IN COMPUTER-ASSISTED TOTAL KNEE ARTHROPLASTY – INCORPORATING THE SOFT-TISSUES

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#### INTRODUCTION

Most femoral component planning systems for computer-assisted TKA are primarily based on bone alignment criteria, with few algorithms incorporating soft-tissue based constraints such as equal joint space gaps in flexion/extension. The variability of landmark digitization for determining femoral rotation has been demonstrated to be non-negligible, however, and can be worse in MIS. Ligament data may help to resolve some of the planning issues, although it also introduces new questions, such as how much force should be applied and does the amount of force or the position of the patella have any significant effect?

#### OBJECTIVES

We are currently developing an intelligent measurement and actuation tool to help plan femoral implant placement in navigated TKA, which could help us in addressing some of the abovementioned challenges. The system has the capability to precisely and independently control either the height or the applied force in the medial and lateral knee compartments, and to record those relationships at any flexion angle with the patellofemoral joint *reduced*.

#### MATERIALS AND METHODS

The *PIKASSO* (Praxim Intelligent Knee Active Spacer System Optima) was designed to fit inside the knee after the tibial cut but before any femoral cuts have been made, so that measurements can be incorporated into a complete planning of the 6 degrees of freedom of the femoral component taking into account the actual tibial cut plane. The miniature device has two sets of tiny linkages that constrain two upper plateaus (medial and lateral) to be parallel to the tibial base plate with a minimum clearance height of ~6mm. The system is fluid-powered and instrumented with pressure sensors, and is driven by a controller embedded into the Praxim station, an image-free navigation system that uses morphologic statistical models deformed to intra-operatively acquired points on the bone surface (BoneMorphing) to create a complete 3D joint model.

#### RESULTS AND DISCUSSIONS

Initial experiments on the usability and accuracy of the device on synthetic and cadaver bones are promising (<1mm), and a full cadaver trial is currently underway. In the static mode, *PIKASSO* acts as a static spacer block with the height being automatically fixed in each compartment as a function of the flexion angle. Pressure measurements indicate the amount of force acting on each plateau while the surgeon manipulates the knee and performs varus/valgus stress tests and records the degree of laxity. In the dynamic mode, the spacers work interactively in real-time with the planned relative positions of the virtual femoral and tibial implants as tracked by the navigation camera, permitting the surgeon to validate the proposed planning with respect to the knee joint laxity, stiffness and ROM. This method allows the surgeon to simulate a trial reduction before any femoral cuts are made based on the current planned femoral position. An interesting aspect of this enabling technology is the potential to suppress the real trial reduction phase, saving time, instrumentation and costs.



## P44

### **MORSELLISED BONE UNDER COMPRESSION AND TORSION IN FEMORAL CANAL-LIKE CAVITY: COMPARISON OF EXPERIMENTAL DATA AND FINITE ELEMENT SIMULATIONS;**

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Impacted morsellised bone is broadly used in revision hip surgery, but its mechanical properties are scarcely understood. The present work reports experimental results where impacted bone was loaded in shear and compression in a geometry mimicking the femoral canal, and evaluates the continued validity of the solid linear viscoelastic model in this new configuration.

A steel cylinder with tapered cavity and fitting spear-shaped steel piston mimics a femoral canal and orthopaedic implant. Morsellised bone is filled into the cavity and impacted by the piston. Following the last impaction stroke, the piston is left in the cavity as prosthesis. It is then loaded axially with 1000 N for 120 min. Axial torsion of 6 Nm is then added and held for further 120 min. Axial displacement and rotation of the prosthesis are registered as functions of time. Additionally a finite element (FE) model is designed, using Abaqus, reproducing the implant and the surrounding wall of morsellised bone. The contact between polished surface of the steel prosthesis and ground bone is assumed frictionless and the contact with the rough steel of the cavity is assumed fixed. The Abaqus material model is a so-called time domain viscoelasticity corresponding to a generalised Kelvin model.

The experiment showed a slowly increasing displacement of the spear sharply accelerated by the torsion. The FE model managed to reproduce qualitatively the experimental results but did not reach the large displacements observed. These results suggest that morsellised bone in this new configuration cannot be described as a viscoelastic solid. The low cohesion of the material indicates that it behaves as a viscoplastic fluid or solid.

## P45

### ACCURACY OF A SIMPLIFIED LEG LENGTH MEASUREMENT ALGORITHM IN TOTAL HIP ARTHROPLASTY

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Leg length inequality is a major source of dysfunction and dissatisfaction following THA. Small changes in adduction/abduction, flexion/extension, or internal/external rotation between pre- and post-reconstruction measurements can lead to significant errors in assessing leg length changes during surgery and can lead the surgeon to make poor decisions based on this inaccurate information. Two prior computer-assisted methods of measuring leg-length change during surgery have had significant problems. To address these problems, a method was developed where the femoral reference frame is tracked in the pelvic coordinate system before and after reconstruction.

42 patients underwent CT-based computer-assisted THA with the new leg-length measurement algorithm and using a tissue-preserving approach through a superior capsulotomy. Pelvic and femoral skeletal reference frames were applied and the leg was placed in a clinically neutral and straight position. Leg-length changes were then quantified by measuring the leg-length discrepancies on the post-operative and pre-operative x-rays. This was achieved by drawing a horizontal line between the tear drops and then measuring down orthogonally to the most proximal points on the lesser trochanters. The x-ray magnification was normalized using the known diameter of the acetabular component.

Compared to radiographic leg-length change, the simplified computer-assisted method had a mean difference of  $-0.2 \text{ mm} \pm 2.0$  (range  $-4.9 - 4.8 \text{ mm}$ ) There was no statistically significant difference between radiographic data and the navigation data [p-value = 0.807].

The current simplified method of measuring leg-length changes during surgery appears to be accurate and efficient. The method eliminates the need to establish a femoral coordinate system and eliminates the need to calculate the center of rotation of the arthritic hip joint, which is often not possible to do. It is likely that this methodology will apply equally as well to image-free navigation and to any other image-based navigation. The addition of more procedures will improve our assessment of this simplified method of measuring leg-length change during surgery.

## **P46**

### **THE MANAGEMENT OF THE VERSION ABNORMALITIES IN DEVELOPMENTAL DYPALSIA OF THE HIP WITH STEM-SLEEVE MODULARITY IN TOTAL HIP ARTHROPLASTY**

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Twenty patients affected by arthrititis of the hip secondary to developmental dyspalsia who had been managed with primary total hip arthroplasties with insertion of the S-ROM stem (De Puy Orthopaedics Inc. Warsaw, Ind.) were prospectively studied.

There were 4 men and 16 women. The mean age was 61 years. The diagnosis was dyspalsia for 9 hips, low dislocation for eleven (Hartofilakides classification). There were a great variety of the shape of the femoral canal and the neck antiversion. No one had had previous proximal femoral osteotomy

Every patients were available for clinical review at a mean of 4 years (range, 48 to 65 months). At this time, the mean preoperative Harris hip score of 52 points (range, 12 to 79 points) had improved to a mean of 80 points. We recorded two intraoperative femoral fracture during the preparation of the femoral canal. One patient had had a revision because of recurrent dislocation. We had no nerve palsy and excessive limb lengthening.

Radiographic examination revealed in 17 case evidence of a stable bone ingrown. No evidence of progressive stem subsidence or a change of stem position. Osteolysis was seen in two femur and was limited to the Gruen zone I. Five Brooker classification grade III ossification were recorded.

The S-ROM had important options for managing the anteverted femoral neck thanks to the use of a distally fixed implant and the proximally modular prosthesis in which the neck and the distal part are one single piece.

The presented findings show the short-term efficacy of the implant in the management of the version abnormalities in dyspalsia and low dislocation form of developmental dyspalsia of the hip. Longer follow-ups and a larger number of patients are needed before the durability of this implant can be assessed. Our results should be considered encouraging.

## **P47**

### **CONTROLLING PAIN AFTER TOTAL HIP AND TOTAL KNEE REPLACEMENT USING A MULTIMODAL APPROACH WITH LOCAL PERIARTICULAR INJECTION: A PROSPECTIVE RANDOMIZED STUDY**

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#### **INTRODUCTION**

Patients undergoing total knee and total knee replacement are often most apprehensive of postoperative pain. Optimal pain control improves patient satisfaction and functional recovery.

The purpose of this study was to describe a novel periarticular injection and to evaluate its effects on pain control, narcotic consumption, and recovery of function after total joint replacement.

#### **METHODS**

An IRB-approved prospective randomized study was conducted to compare different preoperative pain management protocols. For total hip replacements, patients were randomized to either the PCA or the periarticular injection group and for total knee replacements, patients were randomized to the PCA plus femoral nerve block (FNB) or the periarticular injection group. Eighty three patients (45 hips and 38 knees) were enrolled.

In addition all patients all received an involved protocol including preoperative analgesics, anti-inflammatories, patient education, and advanced rehabilitation.

In the injection group, a local proprietary mixture of five medications with different mechanisms of actions was injected into the periarticular sites.

Patients were assessed for pain (visual analog scale) and recovery of functional milestones, (unassisted walking, stair-climbing, straight leg raise), and overall satisfaction at POD # 1, 2, 3 and 14 as well as 6 weeks and 3 months after surgery.

#### **RESULTS**

Patients in the hip injection group demonstrated significantly lower average pain scores on each day of admission (3.8 vs 5.77 on POD # 1;  $p=0.0067$ ). Narcotic use and associated side effects were significantly lower in the injection group. Straight leg raise and overall satisfaction were significantly higher in the injection group (52% vs 15% and 9.2/10 vs 6.7/10 respectively).

Average pain scores and overall patient satisfaction were comparable between the knee injection group and the PCA + FNB group. The knee injection group demonstrated lower narcotic usage and associated side effects. Additionally, 63% of the patients in the knee injection group were able to straight leg raise on POD #1 versus 21% in the PCA + FNB group.

#### **DISCUSSION AND CONCLUSION**

Periarticular injection with a multimodal protocol was shown to decrease pain and improve functional recovery compared to conventional pain control modalities.

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## **P48**

### **THE EFFECT OF OBESITY ON WEAR RATES OF HIGHLY CROSS LINKED ULTRA HIGH MOLECULAR WEIGHT POLYETHELENE**

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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 polyethylene under study is irradiated to 10 Mrads to achieve cross linking, and cold annealed, but not remelted. The purpose of this study was to observe the effect of obesity on linear wear.

#### **METHODS:**

Thirty-nine consecutive highly cross-linked liners (36 patients) were followed for a mean 5.3 years (range 4.1 to 6.1 years). Obesity was defined as a Body Mass Index (BMI) greater than 30. Nine obese patients had a mean BMI of 33.2 (range 30 to 39). The remaining 30 patients had a mean BMI of 25.1 (range, 18.8 to 28.3). All surgeries were performed by a single surgeon using the same femoral and acetabular component designs. Linear wear was measured utilizing Martell's computerized technique.

#### **RESULTS:**

There were no cases of osteolysis noted on plain radiographs. The mean wear rate for the obese group was 0.024 mm/yr (SD = 0.060) versus 0.025 mm/yr (SD = 0.053) for the non-obese group. There was no statistically significant difference in wear rates between the two groups. There were no cases of symptomatic loosening in either group.

#### **CONCLUSION:**

Cross-linking has been shown to improve wear performance of ultra high molecular weight polyethylene. This study shows wear rates in obese patients are similar to those in the non-obese at mid-term follow-up. Highly cross-linked polyethylene significantly reduces wear and may minimize future osteolysis thus increasing the longevity of total hip arthroplasty.

## **P49**

### **USE OF THE TIBIALIS ANTERIOR TENDON AS A LANDMARK FOR EXTRAMEDULLARY TIBIAL ALIGNMENT IN TOTAL KNEE ARTHROPLASTY (TKA): AN ANATOMICAL STUDY**

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#### **INTRODUCTION:**

Radiographic alignment has been well documented as a major predictor of success in TKA. There is a paucity of literature regarding landmarks for the appropriate use of extramedullary alignment. The purpose of this study was to evaluate the accuracy of using the tibialis anterior tendon (TAT) as a distal landmark for extramedullary alignment in TKA.

#### **METHODS:**

Forty-five consecutive ankle Magnetic Resonance Images (MRI) were reviewed in forty-three patients. Axial T1-weighted images just above the articular surface of the tibial plafond were selected for analysis. Measurements were made from computerized images using a digital ruler accounting for magnification. The distance between the midpoint of the distal tibia (point M) and the TAT was recorded.

#### **RESULTS:**

Forty-one of forty-five TAT were medial to Point M (91.1%) while four (8.9%) were lateral. The mean distance for both groups was 1.89 millimeters from Point M (range, 0 to 4.5) (ninety-five percent Confidence Interval 1.45 to 2.33). For seven (15.6%) MRI, there was no distance between the TAT and point M. Thirty-eight of forty-five TAT (85%) were within 2 millimeters of Point M.

#### **DISCUSSION:**

The TAT is an easily palpable fixed anatomical structure that corresponds very closely to the midpoint of the distal tibia. Eighty-five percent of TAT were within 2 millimeters of midpoint of the distal tibia. The authors believe that using the TAT as a distal landmark will help the surgeon identify the center of the distal tibia and will eliminate the surgeon's estimation that is commonly used in current techniques.

## **P50**

### **FAILURE MODES IN REVISION TOTAL KNEE REPLACEMENT**

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#### **INTRODUCTION**

The prevalence of revision total knee replacement is increasing. The purpose of the current study is to understand the ways in which revision total knee replacements fail.

#### **METHODS**

Between 1994 and 2005, 140 revision total knee operations were performed by 4 surgeons at one center. In this time 18 knees presented with a failure of revision TKR. Clinical and radiographic records were reviewed to assess cause of failure and treatment.

#### **RESULTS**

Eight knees had aseptic loosening of 1 or both components. In 7 the quality of the cement mantle within the metaphyseal bone was inadequate. Six knees were revised with more fully cemented intramedullary stems with a constrained condylar insert or a rotating hinge, while one patient died during evaluation. The 8<sup>th</sup> case had fully cemented stems, but developed a circumferential lucency at the femoral interface, treated conservatively. Seven knees were evaluated for infection of the revision TKR. All of these had previously had infection as the reason for the revision. 2 knees were diagnosed with mediolateral instability. One was revised to a rotating hinge, while one was successfully treated with a thicker constrained condylar insert. A third case developed an acute lateral patellar dislocation with anterior instability 9 years after revision TKR. She was medically unstable and unable to ambulate for a year, and was treated with closed reduction and bracing.

#### **DISCUSSION**

Loosening and instability are the most common modes of failure in aseptic revision TKR. The risk of post-operative infection is much higher in the face of previous infection.

## P51

### STIMULUS-EVOKED NERVE MONITORING SYSTEM IN TOTAL HIP PROSTHESIS: PRELIMINARY RESULTS

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**INTRODUCTION:** Nerve palsies after hip prosthesis occur with a frequency ranging from 0.6 to 2.9 after primary implants and from 1.8 to 7.6 after revision. In about one third of patients a permanent paralysis or paresis remains, while in the other patients a (partial) recovery usually takes at least one year, delaying rehabilitation and increasing costs and legal claims. Among known reasons for nerve palsies after hip surgery there is the incorrect positioning of the surgical retractors. Although somato-sensory evoked potentials have been successfully tested in a research environment to monitor the correct position of the surgical retractors, they suffer the following disadvantages, that prevent a larger use in the clinical setting: high costs, logistically demanding, provide only indirect information about motor nerve damage.

We present the preliminary results of a new monitoring system of the positioning of the surgical retractors, based on a “stimulus-evoked” response. The system is composed by an electrical stimulating device, that delivers an appropriate stimulus through the surgical retractor, previously isolated with a disposable plastic film. If the surgical retractor is positioned too close to a nerve, a motor response will then be visible as a muscle contraction and the retractor may be repositioned by the surgeon in a safer area.

**MATERIALS AND METHODS:** Based on the available literature data and on original animal experiments performed in sheeps a prototype stimulating device was developed with the following stimulus parameters: intensity: 9mA; duration: 200 microsec; frequency: 0.3 Hz. The prototype was tested in a consecutive series of 134 patients (92 primary hip prosthesis and 42 revision), randomly assigned to a monitored or unmonitored (control) group. All the intervention were performed in the supine position with constant femoral nerve monitoring.

**RESULTS:** There were no femoral nerve paresis in the monitored group (n=50 patients), compared with 2 paresis in the control group (n=84). The number of alarms were 10 in the 50 monitored patients. No side effects connected with the use of the stimulating device and no interference with the electro-bistoury were observed.

**CONCLUSIONS:** Hip prosthesis is one of the most successful and widely performed procedures in orthopaedic surgery. Nerve lesions, although relatively rare, are a serious complication that may lead to permanent paresis or paralysis and are a potential source for legal claims. The results of the present study point out the possibility to develop a simple and effective device that, acting as an “electronic prophylaxis”, may prevent or at least significantly reduce unwanted nerve lesion, driving a safer positioning of surgical retractors.



## P52

### **PLATELET-RICH PLASMA AND MORCELLIZED BONE GRAFTS FOR TWO-STAGE CEMENTLESS REVISION OF SEPTIC HIP PROSTHESIS**

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**INTRODUCTION:** Hip prosthesis infection is often associated with wide bone loss, due to the infection process, prosthetic loosening and necessary surgical debridement. The use of cementless prosthesis for two-stage revision of failed septic hip prosthesis has been proved to be effective by different authors, but little is known about the safety and efficacy of biological factors to assist and stimulate bone healing in revision surgery after infection. Autologous Platelet-Rich Plasma (PRP) contains, among others, “Platelet-derived growth factor (PDGF)”, “Transforming growth factor-beta (TGF-β)” and “Vascular endothelial growth factor (VEGF)” and it has been proved in different clinical settings to promote bone healing, while having a quite favourable cost and safety profile. We here report on the medium term results of the use of PRP and autologous or homologous morcellized bone grafts in previously infected hip prosthesis.

**MATERIALS AND METHODS:** From May 2002 to June 2004 nine patients with Grade III or IV proximal femoral bone loss according to Paprowski classification underwent two-stage revision for septic hip prosthesis with the same protocol. All the patients underwent a first intervention for infected prosthesis and cement removal, accurate debridement and implant of a preformed long stem antibiotic-loaded cement spacer (Spacer G, Tecres, S.p.A.). Isolated microorganisms were: Coagulase negative in 5 patients, Staphylococcus aureus in 3 patients, Pseudomonas aeruginosa and mixed flora in 2 patients. At 8 to 12 weeks, after clinical and laboratory testing to exclude the presence of infection, the spacer was removed and a cementless modular revision prosthesis was implanted (Profemur, Wrigth Inc.). During this surgical procedure 60 to 110 ml of the patient's blood were taken from a peripheral vein and processed with the SYMPHONY Platelet Concentrate System (DePuy Inc.); the Platelet-Rich Plasma – PRP obtained in this way was then mixed with autologous (2 patients) or homologous (7 patients) morcellized bone grafts and applied in the proximal third of the femur and, in one patient, also in the acetabular defect. Patients evaluation has been performed clinically, radiographically and with laboratory testings at 3 – 6 – 12 and 24 months.

**RESULTS:** In all the patients bone healing occurred at the site of grafting, with consistent bone apposition on the prosthetic surface as demonstrated by radiographic findings. No infection recurrence or aseptic loosening was observed at the latest follow-up.

**CONCLUSIONS:** Autologous platelet concentrate and morcellized bone grafts may be safely used in cementless two-stage revision in infected hip prosthesis, but further studies are necessary to establish if PRP is able to really increase or speed up bone healing in this clinical setting. The possibility to enhance bone healing is particularly attractive in view of the latest findings of an active role of the osteoblasts in bone infections.

## P53

### COMPOSITE MATERIALS AND HIP REPLACEMENT MANUFACTURE FOR THE YOUNGER PATIENTS

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Composite materials are high performance materials widely used in engineering where anisotropy is required. It is therefore surprising that it is not more widely used in orthopaedics as bone structures are highly anisotropic. Attempts have been made to use carbon fibre reinforced plastic materials for hip replacement, but these were shown to fail early, and composite materials for orthopaedics fell in discredit. This is believed to be due to poor design of the implants. The manufacturing methods, and validation against carefully defined design requirements of a novel carbon fibre hip replacement for younger patient (50-70 years) is presented.

Design windows are defined for optimum stability, interface properties, and load transfer to the surrounding bone, as well as biocompatibility. Manufacturing of the stem involves the development of dedicated techniques. Design verification involves testing to ISO7206, under high, complex loads. The interface motions and strength are tested using a specifically designed methodology, fully presented elsewhere.

Initially, the optimum stiffness distribution in the stem is obtained using Finite Element modelling with the objective of restoring normal stress distribution in the femur. The optimum distribution is three dimensional; such stiffness gradients can only be achieved with composite materials and a complex architecture. The stem is manufactured using the resin transfer molding technique, and the reproducibility of the technique is verified during fatigue testing. The ability of the stems to sustain impact as well as interrupted loads is also investigated. The motions at the interface must remain below 150 microns for initial stability and the interface stresses in the bone must remain below 2MPa, whilst the coating adhesion to the stem must sustain *in vivo* loads. The adhesively bonded hydroxylapatite coating has been specifically developed, together with the corresponding spraying technique. The motions at the interface during testing remain below 20 microns proximally. All materials are shown to be biocompatible.

The younger patients' joint replacement market is more demanding than that of conventionally older patients. The consequences of design faults will be more catastrophic as the body reactions to the implant will be faster. The implanted components will also be subjected to higher loads, of variable nature, amplitude and frequency. The complex requirements can be best simultaneously fulfilled by use of complex composite structures. Such a stem can only be developed in parallel with dedicated manufacturing techniques.

## P54

### CT-BASED SURGICAL PLANNING SOFTWARE PROVIDES RIGHT SIZE OF FEMORAL COMPONENT IN CEMENTLESS TOTAL HIP ARTHROPLASTY

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**BACKGROUND:** Precise preoperative planning is important as component Placement critically affects the performance and longevity of cementless total hip arthroplasties (THA). To our knowledge there is no report which quantifies the ideal contact area between host bone and femoral components in cementless THA. Therefore we assessed the area of stem surface in contact with the cortical bone using a CT-based surgical planning software called Hip-OP.

**MATERIALS AND METHOD:** A total of 46 hips were implanted in neutral position (within 2 degrees of varus or valgus) and enrolled for this study. All cases used the same type of prosthesis (Versys cementless fiber metal taper stem, > Zimmer Warsaw). 42 hips were well functioning without subsidence in spite of full weight bearing immediately after surgery. 4 hips showed subsidence within 1 month post-op. All 46 hips were evaluated retrospectively using the Hip-OP 3-D-templating system to provide a ratio between stem surface area and cancellous and cortical bone.

**RESULTS:** The ratio of the stem surface area in contact with cortical bone in patients without subsidence was on average 6.14% (range 4.82% to 7.92%). The contact area was distributed evenly throughout medial and proximal part of the femoral component. In patients with subsidence the average of 2.00% (range 0.05% to 3.70%) was significantly lower than in patients without subsidence.

**DISCUSSION AND CONCLUSION:** In cementless THA, incorrect sizing can lead to subsidence or valgus/varus implantation. The result of this study contribute to resolve these problems. The Hip-Op planning system will aid in choosing the correct size of femoral components in cementless THA.

## **P55**

### **COMPARISON OF TORSION STIFFNESS OF TOTAL HIP PROSTHESIS**

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#### **INTRODUCTION**

The rotational stability of cementless hip prostheses corresponds to their appropriate contour design. The appropriate contour design of a femoral stem is important for secure primary fixation. This paper addresses the issue of the fixation method of hip stems and their rotational stability.

#### **MATERIAL & METHODS**

Different kinds of finite element models of four femoral stems were constructed for computer simulation. These models had contour designs which aim to facilitate tight mechanical fixation in different ways. Boundary and initial conditions were: (i) rigid contact of the distal end of the model femur with the rigid base; (ii) a stepping load of 1800 N was applied to the proximal tip of the stem; (iii) a load of 1440 N was pulled from the greater trochanter of the femur as muscle force; and (iv) a torsion load of 18.9 Nm was applied to the proximal femur as the intra-rotation.

#### **RESULTS**

As a result, it was found that the torsion stiffness of the Intra-Medullary Cruciate stem was 2810 Nm/rad. For the VerSys stem, the torsion stiffness was 1500 Nm/rad. The VerSys stem had a large rotation. The torsion stiffness of the PerFix SV stem was 1630 Nm/rad. The torsion stiffness of the Duetto SI stem was 2420 Nm/rad.

#### **DISCUSSION & CONCLUSIONS**

Judging from torsion stiffness, two types of stem (Intra-Medullary Cruciate stem, Duetto SI stem) provided rotational stability.

## P56

### ENDOASCULAR STENTING OF AN INTIMAL LESION WITH ACUTE LIMB ISCHEMIA OF THE UPPER EXTREMITY AFTER SHOULDER HEMIARTHROPLASTY: A CASE REPORT

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Intimal ruptures with limb ischemia of the upper extremity after joint replacement are very rare. However, they are described in cases of traumatic joint dislocation and direct open surgical repair has been the indicated treatment.

We report a case of a 60 year old male patient presenting with pain, paraesthesia in the fingers, and a cold, pulseless hand 14 hours after shoulder hemiarthroplasty. Immediate angiographic examination showed the subtotal occlusion of the axillary artery due to an intimal rupture that occurred probably either with joint dislocation or with positioning of an instrument intra-operatively.

Direct surgical repair could be avoided by percutaneous angioplasty and primary stenting of the axillary artery using a 6.0 x 30 mm Bard Luminex self expanding Nitinol stent. Follow-up color duplex ultrasonography was performed immediately after intervention and again at three months follow-up. It showed a complete and persistent revascularisation of the artery. Lingering adverse physical symptoms have not been noted in this patient. He recovered with a restored pulse and normal skin color immediately post-intervention, his paraesthetic sensations are ongoing to improve.

Endovascular stenting is a minimal invasive therapy and an attractive option for treatment of postoperative limb ischemia due to intimal disruption after joint replacement, even in unusual sites.

## P57

### **A CASE REPORT OF OSTEOARTHRITIS OF BOTH KNEES WITH EACH OF TOTAL KNEE ARTHROPLASTY INCLUDING AUTOGENOUS BONE GRAFTING AND HIGH TIBIAL OSTEOTOMY IN THE SAME PERIOD OF TIME: A 20-YEAR FOLLOW-UP**

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A woman aged 69 years (at surgery) had complained of severe pain of both knees and serious disabilities on daily activities including walking. The left knee joint showed severe hydrops and the range of motion from 15° to 110° while the right knee joint had mild hydrops and the range of motion from 15° to 130° preoperatively. Radiographic examinations revealed osteoarthritis of both knees with loss of the medial joint space and significant bony destruction and defect of the left medial tibial condyle that extended to the most area of the medial joint surface and the depth of 4 cm from the joint surface at the deepest.

The left knee joint underwent total knee arthroplasty (TKA) with a considerable amount of autogenous bone grafting upon the osseous defect of the medial tibial condyle. The right knee joint received high tibial osteotomy (HTO) in about 3 weeks after the TKA of the left knee joint. The femorotibial angle (standing) of the right knee joint was 184° preoperatively and 167° postoperatively.

Both knees had no pain and disabilities on daily activities such as walking, ascending and descending stairs except full squatting for 9 years postoperatively. They showed the same range of motion from 0° to 135° and no hydrops. The complete and solid union of the grafted bone and the left medial tibial condyle had been obtained and a little medial joint space of the right knee had been observed through radiographic examinations.

The right knee joint (HTO) started to occasionally have mild pain and hydrops even though they did not influence daily activities whereas the left knee joint (TKA) had no pain and hydrops in 10 years after surgery. Since 11-12 years postoperatively, the right knee joint had been painful and had moderate-to-severe hydrops that had affected daily activities whereas the left knee joint had had no pain and hydrops. The medial joint space of the right knee was found to be lost again in 17 years postoperatively.

In 20 years after surgery, the left knee joint (TKA) occasionally had mild pain but no hydrops that did not influence daily activities. The range of motion was from 0° to 135°. There was no radiographic evidence of loosening and absorption of the grafted bone. The right knee joint (HTO) had moderate pain and severe hydrops with the range of motion from 0° to 115°. The walking distance was limited to 100-500m while ascending or descending stairs in bipedal fashion was impossible even with aid because of the right knee pain.

In spite of the left knee joint having had severer arthropathy, it had better long-term outcome than the right knee joint. It suggests that TKA would be more reliable than HTO for osteoarthritis of the knee joint in long-term results.

The successful autogenous bone grafting indicates that it should be considered even for significant osseous defect with TKA before metal block augmentation is chosen.

## **P58**

### **CALCIUM PHOSPHATE PASTE CAN PREVENT THIGH PAIN AFTER CEMENTLESS THA**

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One of major problems in Total Hip Arthroplasty is thigh pain. We have examined the effect of femoral canal injection of Calcium Phosphate Paste (CPP) for cementless THA. CPP is a mixture of alpha Tri-Calcium Phosphate, Tetra-Calcium Phosphate, Calcium Hydrogen Phosphate and Hydroxyapatite. This paste harden in 10 minutes and its stiffness increases to maximum in 3 days.

Cementless THA were performed in 78 osteoarthritic hips from 1999 to 2004. Eight of patients were male and 65 were female, average age were 62.1 years old ranged 39 to 81. Follow-up period were minimum 2 years. Proximal part of the stem was HA coated on rough metal surface. In 19 hips, CPP (10-12g) were filled as a femoral canal filler around the distal end of stem. In 59 hips, as a control, no CPP were filled in the canal.

No thigh pain was observed in CPP group patients. In control group, nine hips (15.3%) showed thigh pain ( $p < 0.026$ ), but walking disability and pain were mild in the first year and improved by the next year.

CPP filled in the canal were absorbed slowly on X-ray film, but prevention of thigh pain lasts for long time maximum 5 years. No infections and pulmonary embolism were observed in both series. Filling CPP into the gap between stem tip and femoral canal is useful technique to prevent thigh pain after cementless THA.

## P59

### TOTAL KNEE ARTHROPLASTY AFTER FAILED HIGH TIBIAL OSTEOTOMY

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#### Objectives;

The aim of this study is to evaluate the post-operative results for patients who undergo Total Knee Arthroplasty (TKA) after failed High Tibial Osteotomy (HTO).

#### Materials & Methods;

Fourteen patients 17 knees who underwent TKA after failed HTO ( H group; Male 2, Female 15, 72 years old, ranged from 67 to 83 ) were included in this study. The intervals between HTO and TKA averaged 62 months (range, from 4 to 192). Evaluation items were as follows; Japanese Orthopaedic Association score (JOA score), range of motion (ROM), flexion Achievement ratio (FAR= post-operative flexion angle / pre-operative flexion angle $\times$ 100(%)) were examined as clinical examinations, and Femoro-tibial angle (FTA), alignments of components and Insall-Salvati ratio were calculated as X-ray photographic evaluations. These data obtained were compared with those in primary TKA (P group; 179 knees) in our department. Statistical analysis was performed with Mann-Whitney U test. The significant value was set up at  $p = .05$ .

#### Results;

In H group, JOA score improved from 51.4 points pre-op. to 70.0 points post-op., ROM changed from  $-5.5/117.7^\circ$  pre-op. to  $-0.5/104.5^\circ$  post-op. and mean FAR was 91.5%. On the other hand, in P group, JOA score improved from 51.9 points pre-op. to 79.0 points post-op., ROM changed from  $-9.1/117.7^\circ$  to  $-0.9/116.0^\circ$  and mean FAR was 103.0%. FAR in H group is significantly lower than that in P group. As for radiological examinations, FTA changed from  $167.5^\circ$  to  $170.8^\circ$ , and alignments of components were good ( $\alpha: 99.2^\circ$ ,  $\beta: 91.3^\circ$ ,  $\gamma: 4.42^\circ$ ;  $\delta: 87.0^\circ$ ) in H group as same as in P group. There were no statistical differences of radiological evaluations between the 2 groups.

#### Discussions;

HTO is widely accepted as a treatment option in patients with medial unicompartmental osteoarthritis of the knee joint. The efficacies were thought to be good and stable. However, of these patients, there were some cases to require additional surgeries, such as TKA. TKA after HTO is a technically more challenging procedure than primary TKA, and has some technical problems. First, it is difficult to expose operative fields widely because of difficulty with patellar eversion due to the shortening of patella tendon. Second, it is difficult to decide the position of tibial component because of the discrepancy between the long axis of tibia and the center of tibia surface. Third, it is difficult to control lateral instability in the point of soft tissue balance. Anyway, we think mechanical axis is the most important to correct the alignment of lower extremity, and component with stem sometimes would be needed.

Our study concluded that the post-operative results of TKA after HTO were almost as good as those of primary TKA except for FAR.



## **P60**

### **USING SURGICAL NAVIGATION AS A TOOL TO ASSESS IMPLANT DESIGN DIFFERENCES INTRA-OPERATIVELY**

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Many surgeons are aware that surgical navigation provides more predictable outcomes related to component placement and overall alignment of the leg for total knee arthroplasty. There has been frequent discussion related to coupling navigation with minimally invasive procedures where visibility is limited. There is one prior report demonstrating the ability to assess implant design differences intra-operatively using surgical navigation. Parameters such as stability and range of motion (ROM) can be quantitatively assessed and documented. This technique may allow comparative evaluation of design features to identify relationships to kinematic performance of the implant.

We are currently investigating the intra-operative kinematic differences between the Scorpio<sup>®</sup> and Triathlon<sup>®</sup> knee systems (Styker Orthopaedics). Like its predecessor, the Scorpio<sup>®</sup> Knee System, the Triathlon<sup>®</sup> is a single axis total knee system, which is purported to provide greater mid-flexion stability than multi-axis designs. However, the Triathlon<sup>®</sup> has been designed to provide stability through 150+ degrees of flexion, whereas the Scorpio<sup>®</sup> was designed to provide stability through 90 degrees of flexion. Using surgical navigation, we are able to assess stability throughout the entire ROM. This information is documented by the system and then compared to clinical evaluations made throughout the first year post-operatively.

Preliminary results suggest that both implants provide stability throughout the entire range of motion. The greatest amount of instability in the medial/lateral plane, 5 degrees in all cases, was found at 20 degrees of flexion with the final implant in place. The intra-operative results are comparable to the clinical results to date. It is interesting to note that, in our early results, the Scorpio<sup>®</sup> Knee System has exceeded expectations by providing stability through 135 degrees of flexion. This study is an effort to determine if implant design features can be modified to provide documentable intra-operative differences in kinematics that have measured benefits in post-operative recovery and function.

## P61

### **INFLUENCE OF DIFFERENT MANUFACTURING METHODS ON CONTACT ANGLE WETTABILITY CHARACTERISTICS OF JOINT REPLACEMENT COCRMO ALLOYS**

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The effects of metallurgical microstructure on wear resistance of CoCrMo hip replacement implants have been subject to debate. Common manufacturing processes for CoCrMo hips include casting (ASTM F75 alloy) and machining from wrought bar-stock (ASTM F1537 low and high carbon). Cast alloys can be hot isostatic pressed (HIP) and solution heat treated to remove microporosity and homogenize the structure, or they can be used as-cast. The HIP and heat treat (HIP/HT) operations dissolve some of the carbides, typically reducing the carbide volume fraction by 50%. As-Cast CoCrMo has been claimed to have superior abrasive wear resistance by virtue of the higher volume fraction of coarse carbides. However, hip simulator studies have mostly shown comparable wear rates for As-Cast (AC), Cast/HIP/HT (CHH), and High Carbon Wrought (HCW) materials.

One potentially important factor in the wear resistance of hip implants is the lubricity of the surface through its ability to be wet by synovial fluid. In this study, the contact angle of liquid on AC, CHH and HCW CoCrMo alloys has been compared.

Measurements were performed on 25 (coupons) of CoCrMo processed identically to hip implants; five of each type of material (AC, CHH and HCW). Prior to the measurements, the coupons were thoroughly cleaned in an ultrasonic bath of water, acetone, and methanol using a consistent cleaning protocol developed in the laboratory. Lubricity was assessed by a visual contact angle (VCA) measuring technique using a dedicated instrument (Optima by Advanced Surface Technology Inc. / MA). A computer interfaced precision camera captured fast dynamic images of a single droplet as it established contact with the tested surface under controlled conditions. The angle that the settled droplet made to the tested surface was graphically measured and averaged automatically by the controlling software. First, measurements were made with de-ionised water as the liquid. The size and dispensation rate of an optimal droplet size of 0.25  $\mu$ L were controlled by an automatic syringe, and maintained throughout. 5 separate measurements were made on each coupon, giving a total of 25 measurements for each material. Surface roughness of the coupons was also measured with an optical non-contact interferometer (Xi -100 by Ambios Technology Inc./CA).

The average surface roughness (Ra) ranged 12-17 nm; all within a narrow range typical of polishing for Total Hip Replacement femoral heads. This verified that surface roughness as a variable was effectively controlled. The average contact angles with de-ionized water were  $58^{\circ} \pm 3^{\circ}$  for the As-Cast (AC),  $60^{\circ} \pm 3^{\circ}$  for the Cast/HIP/HT (CHH) and  $63^{\circ} \pm 2^{\circ}$  for the High Carbon Wrought (HCW) material. These results demonstrated very little differences in wettability which were not statistically significant. Some measurements were repeated with diluted calf serum (as used in wear testing), containing 20 g/l protein concentration. The results with serum showed slightly more spread among the samples of each material, but even less significant differences between the manufacturing processes.

Therefore, the observed wettability through contact angle measurements of CoCrMo alloys was not influenced by the processing technique.

## P62

### ANALYSIS OF WETTABILITY AND SURFACE ROUGHNESS OF ORTHOPAEDIC IMPLANT COMPONENTS

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The wettability behavior of orthopaedic materials influences the fluid film layer that affects both the friction and wear of the articulating surfaces in total joint arthroplasty [1, 2]. This study examined the wettability of various orthopaedic materials such as alumina, zirconia, cobalt chrome (CoCr), and oxidized zirconium (OxZr). Diamond-like carbon (DLC) coating on CoCr was also examined. Additionally, the effects of curvature radius and roughness were examined by using femoral heads of various diameters.

The contact angle of the liquid droplet on the surface of the material was measured using a visual contact angle technique (VCA- Optima<sup>TM</sup> by Advanced Surface Technology, MA). Contact angle measurement utilizes a precision camera and advanced PC technology to capture static or dynamic images of the droplet. Water and diluted calf serum of 20 g/l concentration was used to study the lubricity of the various orthopaedic surfaces. The droplet was dispensed from an automated syringe with a consistent and controlled droplet size of 0.25  $\mu$ L. The contact angle was then measured by fitting curves to the sample surface and drop geometry. Ten drops were analyzed on each test component, with at least 3 test components for each material. The contact angle for each material was then determined by averaging the measurements obtained on different components of the same material. The surface roughness measurement was performed on a non-contact optical interferometer (Xi-100 by Ambios Technology, CA) which combines the phase-shifting interferometric technology with optical imaging to provide the roughness of the **curves surfaces** with high precision.

A statistical analysis was performed to determine the effect of head size, material, and liquid on the wettability of the surface. A summary of the contact angle measurement results for the various materials was recorded. Although no differences were seen with changing head size, there was a trend that the wettability of the surfaces was higher when using serum compared to water, which may be due to the attachment of proteins onto the material surface. The alumina, OxZr, and zirconia femoral heads all exhibited a similar contact angle, while CoCr and DLC showed a significantly higher contact angle, which indicates a less wettable surface. However, effective contact angle is greatly influenced by the roughness of the articulating surface.

In summary, oxide ceramic materials such as zirconia were found to be more wettable than the CoCr and DLC coated CoCr, which may explain the decreased friction and lower wear found with the orthopaedics ceramic surfaces.

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## P63

### DESIGN RATIONAL AND DEVELOPMENT OF TOTAL ANKLE ARTHROPLASTY USING 3-COMPONENT PROSTHESIS DESIGN

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Total Ankle Arthroplasty (TAA) provides excellent pain relief. Clinical application for TAA started since the 1970's, various TAA prostheses have been developed in the world. Although loosening and sinking of a postoperative early stage remain as problems since the implant is placed under a considerable stress environment. We developed new 3-component design TAA aiming at clinical results acquisition over a long period of time and verified the design.

From the osteotomy surface and CT data of a cadaver bone, contour extraction of the articular surface was performed. Contact stresses on the tibial articular surface were refined using finite element analyses (FEA). An investigation was performed regarding how changes in the joint's range of motion affect the contact area of the surface.

According to the bone cut of TAA, evaluation of an osteotomy side was performed as AP/ML ratio. As a result of 20 cases, the talar AP/ML ratio showed  $1.163 \pm 0.165$ . The tibial AP/ML ratio showed  $1.118 \pm 0.035$ . Based on this result, basic design of prosthesis and a size variation were performed. FEA showed peak von Mises stress of 13.0 MPa under a 3,000 N load, well below the plastic limit of UHMWPe. The overall contact area of the talocrural joint became a constant  $600 \text{ mm}^2$  between  $\pm 10$  degrees of dorsiflexion and plantar flexion. For the 2-component prosthesis under standard conditions, FEA showed peak von Mises stress of 19.5 MPa under a 3,000 N load, the contact area of the surface was  $190 \text{ mm}^2$ .

New 3-component design TAA was developed for the purpose of stress dispersion and easy self-alignment of the ankle joint. From this investigation, it was shown that TAA of 3-component prosthesis is excellent in stress dispersion.

## **P64**

### **DESIGN RATIONALE AND KINEMATIC OUTCOME OF TOTAL KNEE ARTHROPLASTY REPRODUCING ANATOMIC GEOMETRY**

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Total knee arthroplasty (TKA) provides excellent pain relief and reliable clinical outcomes greater than 10 years. However, younger and more demanding patients require even greater implant longevity and functional performance. We hypothesized a novel posterior cruciate-retaining TKA design that restores the anatomical joint line in both sagittal and coronal planes, maintains the femoral posterior condylar offset, and provides low contact stress would provide enhanced patient function with the potential for greater implant longevity.

The novel TKA design was created based on geometry determined from anatomic specimens, 3-degree medial slope of femorotibial jointline was incorporated in the TKA novel design. It refined using finite element analyses (FEA) to minimize peak contact stresses. One year postoperative functional assessment was performed in 10 patients using lateral fluoroscopy and shape matching to determine 3D tibiofemoral motions.

FEA showed peak von Mises stress of 10.5 MPa under 2000 N load, well below the plastic limit of UHMWPe. Kinematic analysis during a stair-step activity revealed an average 13.6° tibial internal rotation with flexion to 100°. Condylar translations exhibited a medial pivot pattern from 0° to 100° flexion, with an average of 0 mm medial condyle translation and 11 mm posterior translation of the lateral condyle. As a result, medial pivot motion was accepted.

The novel cruciate-retaining TKA design based on restoration of articular surface orientation and bony geometry exhibits in vivo kinematics and contact mechanics that are compatible with excellent functional performance and implant longevity.

## P65

### TOTAL KNEE ARTHROPLASTY (TKA) OVER 80 YEARS OLD

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#### PURPOSE

The aim of this study was to investigate the post-operative results of TKA in patients over 80 years old.

#### MATERIALS AND METHODS

Between April 1995 and September 2005, 380 TKA had been performed in our hospital. Of these, 48 cases 60 knees over 80 years old (15.8%; male 5 case 6 knees, female 43 cases 54 knees, mean 83 years at op.) were included in this study (elder group). Follow-up averaged 39 months (range, from 3 to 94). As clinical evaluations, Japanese Orthopaedic Association score (JOA score), range of motion (ROM), flexion achievement rate (AR; post-operative flexion angle /pre-operative flexion angle  $\times 100(\%)$ ), time to start walking and duration of hospital stay were investigated. As radiological assessments, femoro-tibial angle (FTA) was calculated. Moreover, complications and previous illness in each patient were noted.

Statistical analysis was performed using the Student's t test or Wilcoxon signed rank test.

#### RESULT

In elder group, JOA score improved from 48.2 points pre-op. to 76.3 points post-op, ROM changed from  $-11.6^\circ/116.3^\circ$  pre-op. to  $-0.5^\circ/120.2^\circ$  post-op. and AR averaged 103%. Time to start walking and duration of hospital stay were 9.5 days 36.5 days, respectively. On the other hand, in younger group (under 80 years), JOA score improved from 51.9 pre-op. to 79 post-op. points. ROM changed from  $-0.5^\circ/104.5^\circ$  pre-op. to  $-0.9^\circ/116^\circ$  post-op. and AR averaged 103%. Time to start walking and duration of hospital stay were 14.8 days and 45.3 days, respectively. In radiological assessments, FTA changed from  $185.7^\circ$  to  $173.6^\circ$  in elder group, from  $182.6^\circ$  to  $174.2^\circ$  in younger group, respectively. There were no statistical differences of post-operative results between groups in any evaluations.

There were 10 post-operative complications, delayed wound healing, in elder group. High incidences of previous illness were noted in elder group as follows; 33 cardiac system disease, 9 cranial nerve system disease, 24 anemia, 17 kidney function disorder, and 17 lungs function disorder.

#### CONCLUSION

Our study concluded that TKA was very effective for older patients as same as younger ones. Many attentions should be paid for multiple pre- and post-operative complications and previous illness.

## **P66**

### **EVALUATION OF MIS (POSTERIOR APPROACH) FEMORAL HEAD REPLACEMENT**

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Femoral head replacement with an independently improved small incision posterior approach has been performed in the reporting hospital since April 2003. The author verified the minimal invasiveness of our approach by comparing it with a conventional procedure performed before that.

#### **SUBJECTS**

Group A was composed of patients who had undergone MIS (50 joints), and group B undergone a conventional procedure (26 joints). The target condition was femoral - neck fracture in all patients. This study evaluated differences in length of surgery, amount of blood loss, and length of hospital stay between the 2 groups as well as VAS scores and days to successful straight-leg raising (SLR) of those in group A.

#### **KEY POINTS OF THE SURGICAL PROCEDURE**

To accommodate MIS, the following improvements were made: (1) the size, shape, and use of retractors (Dr. Larry Dorrs) manufactured by Zimmer were improved to make them suitable for Japanese, (2) the location of skin incisions was improved (3) in ablating and inverting the short lateral rotators, the piriformis and quadratus femoris were preserved, and (4) for repair, the ablated short lateral rotators and articular capsule were attached to the greater trochanter with the pull-out method.

#### **RESULTS**

The mean lengths of the surgery were 78 minutes for group A and 104 minutes for group B. The mean intraoperative blood losses were 98 ml for group A and 219 ml for group B. The lengths of hospital stay were 27 days for group A and 33 days for group B. The mean VAS score of group A was 3.6/10. SLR could be performed within 3 days after surgery by 41 % in group A.

#### **DISCUSSION/CONCLUSION**

In Japan, femoral head replacement is more common than THA. MIS-THA is a surgical procedure developed in Europe and the United States, and therefore cannot immediately be applied to femoral head replacement. Our method is considered to have been established as a safer and less invasive surgical procedure. In femoral head replacement, the acetabulum does not need to be reamed. Soft tissue disruption varying by approach influences invasiveness of surgery, and femoral head replacement was more appropriate as MIS than THA.