1.

Long-term outcomes of the surface replacement trapeziometacarpal joint prosthesis: a radiostereometric study with 10 years of follow-up

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Background: The optimal surgical treatment of osteoarthritis (OA) of the trapeziometacarpal joint (TMCJ) is still controversial. Although clinical outcomes are good, one of the main drawbacks of TMCJ arthroplasty is loosening and the need of implant revision. The Surface Replacement (SR) TMCJ prosthesis duplicates the saddle-formed anatomy of the joint in order to achieve high implant stability.

Purpose/Aim of Study: The aim of this study was to evaluate the fixation and long-term migration patterns of the SR-TMCJ prosthesis using Radiostereometric Analysis (RSA). Further we evaluated long-term survival and clinical outcomes.

Materials and Methods: Ten patients received the SR-TMCJ prosthesis. RSA-radiographs were obtained direct postoperatively and six months, one, five and ten years postoperatively. Clinical outcomes were evaluated using the Visual Analogue Scale (VAS) of pain, DASH and Nelson scores at all follow-up moments.

Findings/Results: Two prostheses were revised after resp. two and three years. The largest translation was found along the y-axis (mean 0.88mm). Mean translations along the x- and z-axis were resp. 0.25 and 0.43mm. The majority of migration occurred in the first year postoperatively and implants appeared to stabilize after twelve months. Rotation values could not be calculated because of a lack of precision. Mean pre-operative DASH and Nelson scores were 53 and 51. One year postoperatively, DASH and Nelson scores improved to 21 (p=0.003) and 80 (p=0.004) and remained stable throughout the entire follow-up time. Median VAS pain score ten years postoperatively was 1.5.

Conclusions: The SR-TMCJ prosthesis seems to stabilize after one year of follow-up. This study confirms that model-based RSA is an imprecise method to detect rotations of TMCJ implants. The ten-year survival rate is 80% with high long-term patient satisfaction.

2.

Increased migration and more revisions of MOTEC compared with ELECTRA cups. A 2-year RSA study of trapeziometacarpal prostheses

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Background: Cup failure is a recognized problem in total trapeziometacarpal (TM) joint prosthesis. Several cup designs are available but clinical documentation is sparse. Pressfit cups depend on a primary mechanical and secondary osseous integrationy, which may be evaluated with radiostereometric analysis (RSA).

Purpose/Aim of Study: The purpose of this study was to compare cup stability with two cementless screw cups and the possible relation to cup revision.

Materials and Methods: 2 consecutive prospective patient cohorts, Eaton type 2-4, were operated with TM joint prostheses using two differently designed trapezium screw cups: the MOTEC cup with a collar (n=22), and the ELECTRA bimetal cup without a collar (n=22). Mean age was 60 (45-74) years. There were 31 female and 13 males. Model-based RSA was used to measure cup migration with respect to the trapezium, which was marked with 1mm tantalum beads during surgery. Stereoradiographs and DASH score was measured at baseline, 3 and 6 months, and 1 and 2 years postoperative.

Findings/Results: At 2 years total translation of mean 2.32 (sd 2.4) mm with MOTEC cups (n=7) was higher (p=0.01) than mean 0.87 (sd 1.61) mm with ELECTRA cups (n=16). At 3 months total translation was higher in cups that were revised later on (p=0.03). There was a tendency for more subsidence with MOTEC cups (1.03 vs 0.22 mm; p=0.053). There was no significant cup migration between 1 and 2 years (p=0.62). At 2 years the revision rate in the MOTEC group was 41% (9/22), versus 0% (0/22) in the Elektra group (p= 0.02).
There were no significant differences in clinical results between the two groups.

Conclusions: The MOTEC trapeziometacarpal cup with a collar has higher implant migration and more revisions compared with the ELECTRA collarless bimetal cup at 2 years followup. Early migration was higher in cups that were later revised.

3.

Precision of elbow kinematics with dynamic RSA

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Background: Dynamic radiostereometry (dRSA) and bone models can be useful for evaluation of elbow kinematics. During an elbow extension- flexion movement the forearm will be positioned in different areas of the RSA image during a frame-series, which may compromise precision.

Purpose/Aim of Study: To evaluate the precision of dRSA in the elbow including the influence of the position of the forearm within the image.

Materials and Methods: Eight human upper arm specimens were rigidly clamped in a motorized fixture and recorded twice (with repositioning) with dRSA during an elbow flexion motion with the forearm in neutral position. Subject specific bone models of the humerus, radius and ulna were created from CT scans using an automated method. Model-based RSA was used for calibration and initialization of the bone models on the first frame of the dRSA series. Further analysis of the remaining dRSA frames was conducted using an automated digitally reconstructed radiograph analysis method (AutoRSA). Systematic error was evaluated as mean difference between double examination frames synchronized by flexion angle and the precision was evaluated by the standard deviation of these differences. The influence of the forearm position was evaluated on position 15, 60, and 105 degrees of flexion. Only translations were investigated.

Findings/Results: The systematic error in translation was up to -0.27 mm (CI95% -.30 ; -.24) and the precision was up to 0.14 mm. One-way ANOVA showed no difference in the systematic error and random error in the different forearm positions of the specimen ($p>0.29$).

Conclusions: Evaluation of elbow kinematics by dRSA has a precision better than 0.5 mm in all translation axes. The position of the forearm during motion across the image frame does not influence the systematic error or the precision.

4.

Distal Radioulnar Joint stability after foveal TFCC reinsertion compared to ligament reconstruction.
A randomized experimental static radiostereometry study

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Background: The Triangular Fibrocartilage Complex (TFCC) is the main stabilizer of the distal radio ulnar joint (DRUJ). After lesion of the TFCC, stability of the DRUJ can be restored with different surgical techniques, but in-vivo methods to quantify and compare the stabilizing effect of these are missing. We recently described and validated a new and precise digitally reconstructed radiograph(DRR) radiostereometric analysis(RSA) method named AutoRSA for evaluation of joint kinematics by use of CT bone-models.

Purpose/Aim of Study: To evaluate DRUJ stability before and after surgical TFCC reinsertion or reconstruction, respectively.

Materials and Methods: Ten human donor arms (8 males, mean age 78 y) were evaluated with RSA prior to intervention (native), after cutting the proximal and distal TFCC insertions (cut), and again after randomization to foveal reinsertion of the TFCC(n=5) or reconstruction ad modum Bryan Adams(n=5).During RSA imaging DRUJ stability was tested with the Piano Key test in a standardized test-rig. AutoRSA was used for analyses and standardised anatomical axes and coordinate systems of the forearm were used to describe the kinematics and stability.

Findings/Results: In all cadavers, the native DRUJ translated 1.36mm (CI 95 0.17; 2.55), increasing to 2.45mm (CI 95 1.68; 3.22) after inflicted TFCC lesion(p=0.002).Both foveal reinsertion and TFCC reconstruction reduced DRUJ translation towards stability of the native joint, with a tendency of overtightening compared to the native joints(p>0.20).Compared to the cut situation, the DRUJ translation was reduced noticeably after foveal TFCC reinsertion(p=0.008), while the effect of the Bryan Adams procedure was non-significant(p=0.10).

Conclusions: Foveal TFCC reinsertion stabilized the DRUJ markedly, but we did not find significant stabilizing effect of TFCC reconstruction ad Modum Bryan Adams.

5.

Evaluation of implant fixation in reverse total shoulder arthroplasty: A prospective, randomized clinical trial

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Background: Reverse total shoulder arthroplasty (RTSA) is rapidly becoming a promising solution for patients suffering from pain and loss of arm function. Initially designed for patients with cuff tear arthropathy, its growing number of indications and use in younger populations has stimulated a diverse array of designs and fixation methods in use world-wide without long-term follow-ups to support their performance.

Purpose/Aim of Study: The purpose of this study is to evaluate fixation of press-fit and cemented humeral stems, and separately, fixation using bony increased-offset reverse shoulder arthroplasty (BIO-RSA) glenosphere lateralization technique to a novel 3D- printed porous metal augment lateralization technique using model-based radiostereometric analysis (MBRSA).

Materials and Methods: Forty RTSA patients were randomized to either a press-fit or cemented humeral stem, and either BIO-RSA or a 3D-printed porous metal augment lateralized glenosphere. Postoperatively, stereo x-rays were taken at 6 weeks (baseline), 3 months, 6 months, 1 year, and 2 year timepoints and migration measured using MBRSA.

Findings/Results: Preliminary results up to 1 year are presented, as patient follow-ups are ongoing. Significant differences were observed between stems at the 6 month and 1 year timepoints, with press-fit stems showing greater inferior subsidence (-0.85 vs -0.16 mm and -0.83 vs. 0.18 mm, respectively) and total translation (1.10 vs. 0.42 mm and 1.25 vs. 0.31 mm, respectively), though stability was observed from 6 months onward. No differences were observed between glenosphere lateralization groups.

Conclusions: Press-fit stems show a trend towards increased migration in the first six months postoperatively, but all fixation techniques illustrate stability from the 6 month timepoint through one year, and this is expected to continue through two years.

6.

Stable fixation of the stemless humeral component of the Simpliciti Shoulder System: a radiostereometric study with 12 months of follow-up

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Background: Shoulder arthroplasty traditionally relies on intramedullary fixation for its stability. Drawbacks in stemmed arthroplasty include stress-shielding, stress risers, fractures and the need for modularity. Therefore, short stem and stemless devices have been developed with promising clinical results. However, a reduced area of fixation can hypothetically result in less fixation and increased loosening.

Purpose/Aim of Study: The aim of this study is to investigate the fixation and migration patterns of the stemless humeral component of the Simpliciti Shoulder System and to evaluate clinical outcomes.

Materials and Methods: In this prospective cohort study 24 patients received the Simplicity Shoulder System. RSA-radiographs were obtained direct postoperatively and six weeks, six months and twelve months postoperatively. To determine the precision of the technique, double examinations were performed at twelve months follow-up. Migration was calculated using model- based RSA. Clinical outcomes were evaluated using the numeric pain rating score (NPRS), the Oxford Shoulder Score (OSS), the Constant-Murley Scale (CMS) and the DASH score.

Findings/Results: One prosthesis was revised because of infection. At twelve months, mean translation (Standard Deviation (SD)) along the x-, y- and z-axis was 0.27 (0.35), 0.26 (0.29) and 0.45 (0.39)mm. Mean rotation (SD) along these three axes was 0.94° (0.91), 0.57° (0.63) and 0.61° (0.42). Precision of translation and rotation measurements was resp. 0.51mm and 3.03°. The NPRS, OSS, CMS and the DASH score significantly improved twelve months postoperatively.

Conclusions: Fixation of the stemless humeral component of the Simpliciti Shoulder System is good after twelve months. Long-term follow-up is required to relate short term migration to long-term outcomes.

7.

Marker-based versus model-based radiostereometric analysis in randomized controlled trials to identify differences in migration of total knee arthroplasties

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Background: Higher migration of modular metal-backed compared with all-polyethylene total knee arthroplasty (TKA), as found in a recent RCT using marker-based radiostereometric analysis (RSA), may partly result from micromotion of the polyethylene within the locking mechanism of the metal tray.

Purpose/Aim of Study: We therefore investigated whether model-based RSA, using a 3D model of the metal-backed tibial component, would result in different trial conclusions. By doing so, we explored the advantages and disadvantages of each method and quantified insert micromotions within the locking mechanism.

Materials and Methods: 28 patients were re-analyzed. Precision of each method was calculated using double examinations. A linear mixed-effects model was used to analyze group differences between (modelbased) metal- backed and (marker-based) all-polyethylene migration as the primary outcome. Polyethylene insert micromotion was quantified by measuring migration with respect to the metal tray.

Findings/Results: Marker-based and model-based RSA gave comparable mean maximum total point motion results, hence conclusions on group differences remained unchanged. Furthermore, the polyethylene inserts did not show translations or rotations above the RSA precision thresholds. Rotations were less precise in model-based RSA due to inaccuracies in model-fit, marker-based RSA using polyethylene markers overestimated translations and was more susceptible to measurement error in case of marker over- projection. This resulted in substantially different results between both methods for some individual patients.

Conclusions: Although marker-based and model-based RSA gave comparable mean migration results, conclusions on individual patients may differ due to various types of measurement error. The polyethylene inserts showed negligibly small, below precision movements within the tray.

8.

The effect of bone quality on migration in unicompartmental knee arthroplasty. A prospective cohort study using dual x-ray absorptiometry and radiostereometric analysis

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Background: Implant loosening of the tibial component is the most common cause of late revision of knee implants. Altered biomechanical loading at the bone- implant interface and the bone quality surrounding the implant can be of influence on implant loosening. Unicompartmental knee arthroplasty (UKA) is designed to resemble normal knee kinematics and load distribution to the surrounding bone.

Purpose/Aim of Study: The aim of our study was to compare migration of the tibial component in patients with a UKA with normal bone mineral density (BMD) or osteopenia/osteoporosis.

Materials and Methods: The cohort existed of 56 patients with a medial, mobile-bearing (n = 28) or fixedbearing (n= 28) UKA. The cohort was divided in a group with normal BMD (N-BMD) (n = 37) and a group with osteopenia/osteoporosis (O-BMD) (n = 28). Stereoradiographs and dual x-ray absorptiometry (DXA) were obtained postoperatively and at 3, 12 and 24 months. Two regions of interest (ROI) were defined; ROI 1 directly below the subchondral plates of the medial tibial joint surface and ROI 2 at the metaphysis.

Findings/Results: The N-BMD group had a 14% (ROI 1, $p < 0.01$) and a 10.8% (ROI 2, $p < 0.01$) higher BMD as the O- BMD group throughout follow-up. For both groups, BMD showed a reduction between 1 week and 24 months (ROI 1: N-BMD: -11.3%, O-BMD: -13.1% ($p < 0.01$); ROI 2: N-BMD: -8.0% ($p < 0.01$), O-BMD - 8.9% ($p < 0.01$)). No significant difference in MTPM was found between groups at any time point. At 24 months, mean MTPM was 0.45 mm (95%CI 0.36; 0.54) for the N-BMD group and 0.44 mm (95%CI 0.34; 0.54) for the O-BMD group.

Conclusions: Patients with osteopenia/osteoporosis had significantly lower BMD in the tibial bone. Over time a small reduction of periprosthetic BMD was observed. No relation was found between migration of the tibial component of the UKA and osteopenia/osteoporosis.

9.

Similar and good fixation of cementless and cemented Oxford Partial Knee Tibial Trays at 5 years follow-up. A Randomized RSA Study

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Background: Cementless fixation of Oxford® Partial Knee tibial trays is gaining in-pass on the market and has promising results.

Purpose/Aim of Study: To compare fixation of cementless and cemented (gold standard) Oxford® Partial Knee tibial tray up to 5 years follow-up.

Materials and Methods: 79 patients (48 men) were randomly allocated to surgery with cementless (CL) hydroxyapatite-coated (n=25) or cemented (C) (n=54) Oxford Partial Knee tibial trays (Biomet) in a multicenter study. Femoral components were either single-pegged or double-pegged in the cemented group and double-pegged in the cementless group. Refobacin bone cement (Biomet Inc.) was used. Evaluation of implant migration, and clinical outcomes (OKS) was performed at 6 weeks, 3 and 6 months, and 1, 2, and 5 years.

Findings/Results: CL migrated more than C at all follow- ups ($p<0.01$), however migration stabilized at 6 months follow-up. At 5 years CL (n=23) migrated 0.49mm (sd 0.34) and C (n=48) migrated 0.38mm (sd 0.63) mean total translation (p=0.01). 5 year subsidence was higher for CL compared to C (p=0.01). Between 2 and 5 years CL migrated 0.09mm (sd 0.10) and C migrated 0.13mm (sd 0.33) total translation (p=0.48). 16% of CL and 22% of C migrated more than 0.2mm total translation between 2 and 5 years follow-up (p=0.55). At 5 years mean OKS was 39 (range 12-48) and similar between groups (p=0.47) with comparable improvement from baseline (p=0.18). 91.6% with C and 94.1% with CL were satisfied with the result (p=0.91).

Conclusions: Cementless Oxford® Partial Knee tibial trays migrated initially but stabilized at 6 months probably due to osseointegration. Between 2 and 5 years follow-up cementless fixation was as good as cemented fixation (gold standard). Functional results were good and satisfaction high and equivalent in both groups.

10.

TIBIAL FIXATION OF A BICRUCIATE VERSUS A POSTERIOR CRUCIATE RETAINING TKA

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Background: In bicruciate retaining (BCR) total knee arthroplasty (TKA), the pegged tibial component is smaller due to anatomical restriction of the preservation of the cruciate ligaments. This may influence the fixation of the tibial component compared to implants where only the posterior ligament (CR) is retained and a stemmed tibial component is used.

Purpose/Aim of Study: The aim of this study was to compare the tibial fixation of a BCR implant with a CR implant 1 year postoperatively, by using radiostereometric analysis (RSA).

Materials and Methods: In a randomized controlled trial, a total of 40 patients with osteoarthritis received a BCR implant (Vanguard XP, Zimmer-Biomet) or a CR implant (Vanguard CR, Zimmer-Biomet). RSA images were taken at baseline, 6 weeks, 3, 6, and 12 months postoperatively. Micromotion of the tibial implant relative to the bone was assessed using model-based RSA software (RSAcore).

Findings/Results: The median (range) total translation and rotation at 1 year was 0.33 (0.06 to 1.22)mm, and 0.77 (0.34 to 2.25)° for the BCR implant, and 0.29 (0.07 to 0.99)mm, and 0.59 (0.19 to 1.81)° for the CR, respectively. The total amount of rotation was statistically significantly different. Specifically, rotation around the longitudinal-axis and sagittal-axis showed different patterns of micromotion between the groups. On average the BCR implants had a slight posterior tilt (-0.52 [-2.18 to 0.40]°), and rotated more into varus (-0.27 [-1.01 to 0.42]°). Whereas the CR had on average, a slight anterior tilt (0.06 [-0.50 to 1.53]°), and no varus-valgus rotation (0.01 [-0.5 to -0.63]°).

Conclusions: The preliminary results suggest that the BCR tibial implants tilted slightly posterior and rotated into varus compared to the CR implants. The question remains whether these small differences will have any clinical consequences in the longer term.

11.

Is a delayed reference exam more useful for predicting acceptable fixation in cemented and uncemented TKA?

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Background: Uncemented tibial components in total knee arthroplasty (TKA) have significantly higher 1- year migration than cemented, and are often classified as 'at risk' using 6 month and 1 year migration thresholds, despite no stable migration after 1 year.

Purpose/Aim of Study: Our aim was to determine if migration at 6 months and 1 year were equivalent for cemented and uncemented components when calculated from a 6-week or 3-month reference exam, thereby demonstrating the possibility of equivalent early migration thresholds for both types of fixation.

Materials and Methods: Primary TKA cases with complete follows at post-op, 6 weeks, 3 months, 6 months, 1 year and 2 years in our database were reanalyzed using 6 week and 3 month reference exams with 6-month and 1-year MTPM migration calculated.

Findings/Results: 93 TKA (45 cemented and 48 uncemented of 7 different implant designs from 2 centres) were included. 6-month MTPM migration for cemented vs. uncemented fixation was 0.38±0.33 vs. 0.91±0.78, 0.24±0.16 vs. 0.61±0.60, and 0.18±0.11 vs. 0.31±0.27 mm for post-op, 6-week, and 3- month reference exams respectively (mean ±SD, $p<0.001$ between fixation groups for all reference exams). Results at 1-year were similar (statistically significant difference between groups, but most similar when using a 3- month reference exam).

Conclusions: We advocate the use of a delayed reference exam at 6 weeks to reduce patient and institutional burden and potentially increase the accessibility of RSA without a meaningful loss of data about patterns of implant migration. The use of a 3-month reference exam for calculating 6-month and 1- year migrations should be investigated as a possible universal threshold of acceptable migration for all fixations.

12.

Early follow-up of hybrid Total Knee Arthroplasty (TKA) using Persona® prostheses

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Background: Persona® (ZimmerBiomet) TKA has been designed with the aim of minimizing the group of patients with persistent postoperative pain by e.g. an asymmetrical tibial component that allows good coverage of the tibial plateau without the risk of placing the component in in-ward rotation.

Purpose/Aim of Study: Aims: to measure early implant migration and functional outcome after insertion of a primary hybrid Persona® TKA due to osteoarthritis.

Materials and Methods: Thirty-one patients (mean age 65 years, F/M= 18/13) scheduled for primary TKA. One patient was excluded due to PCL rupture and change to ultra-curve insert and one due to competing disease and couldn't participate, leaving 29 to follow-up. Surgeries were performed by 3 experienced knee surgeons, all patients received cemented tibia component, uncemented TM femur component and cemented patella Persona® all poly patella component. Implants were evaluated with Mb-RSA after 7 days, 3, 6, and 12 months. Functional and clinical outcome were evaluated with Knee Society Score (KSS) and Oxford Knee Score (OKS) preoperatively and 1 year after surgery.

Findings/Results: Twenty-nine patients were followed for 1 year and no revision surgeries were performed. The average Maximal Total Point Motion (MTPM) for uncemented femur TM components were at 3 months 0.86 mm (0.28-5.66), 6 months 0.95 mm (0.18-5.74) and 1 year 1.56 mm (0.29-5.84) compared to the 1-week postoperative RSA. For cemented tibia components the average MTPM were at 3 months 0.71 mm (0.28-2.12), 6 months 0.86 mm (0.22-2.09) and 1 year 0.9 mm (0.26-1.97). KSS-clinical showed an increase from 38 (10-79) pre- operatively to 84 (57-93) at 1-year follow-up, KSS-function 54 (10-60) to 92 (60-100) and OKS showed an increase from 25 (13-38) to 43 (32-48).

Conclusions: The early follow-up result is promising, but further long-term follow-up is needed.

13.

Pilot study to evaluate fixation of tibial trays with metaphyseal sleeve revision total knee arthroplasty

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Background: There are a growing number of revision total knee arthroplasty (rTKA) surgeries being performed each year, even as the failure rates of primary TKAs improve. The survivorship of rTKA is dependent on the initial implant fixation and stability which may be compromised by significant bone loss in the proximal tibia and distal femur. The use of cementless metaphyseal sleeves in the proximal tibia is a strategy to improve fixation in the metaphyseal region of the tibia. There have been a number of retrospective studies but there have been no RSA studies on this method of fixation, especially in the heterogeneous rTKA patient population.

Purpose/Aim of Study: This pilot study was completed to determine the migration patterns of revision tibial components utilizing metaphyseal sleeve fixation and long stems.

Materials and Methods: Ten subjects were followed prospectively at 6 weeks, 3, 6, 12, 24 months after surgery to measure tibial component migration using model-based RSA from immediate post-operative reference exams.

Findings/Results: Double exam precision was 0.6 mm (upper limit of 95% CI) for MTPM. The mean MTPM at 1 year was 1.4 mm (95% CI 0.6- 2.1) and 1.6 mm at 2 years (95% CI 0.8- 2.3). Three subjects had patterns of continuous migration after 1 year.

Conclusions: It is becoming increasing clear that gaining initial fixation with augments during revision can improve long-term fixation. There were no failures during the two-year follow up and mean group migration demonstrated a pattern of stabilizing migration. The cases that had continued migration will be followed closely. The results of this study demonstrate the ability of RSA to measure the migration of a complex implant in a challenging patient population and the potential utility of RSA for monitoring individual rTKA cases.

14.

The effect of moulding versus machining on bearing wear in Oxford unicompartmental knee replacement

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Background: The bearings for the Oxford Unicompartmental Knee Replacement (OUKR) are usually manufactured by direct compression moulding but occasionally they are machined instead. In about 2005 there was a change from 1900 to 1050 polyethylene resin.

Purpose/Aim of Study: Our study investigates the wear rate for 1900 & 1050 machined versus 1050 moulded bearings.

Materials and Methods: About 20 patients with ten years or more follow-up with each bearing type were recruited from a cohort of medial OUKR carried out by the designer surgeons. Weight bearing, model based radiostereometric analysis was used to determine the poses of the tibial and femoral components and a custom Matlab routine was used to calculate the minimum distance between the components. This distance was subtracted from the nominal bearing thickness to estimate linear wear. Based on the duration of implantation the linear wear rate was calculated.

Findings/Results: The wear rate for the 1050 (n=23) moulded bearings was 57 μm/yr (SD 30) while the wear rates for the 1050 (n=21) and 1900 (n=19) machined bearings were 76 μm/yr (SD 32) and 60 μm/yr (SD 42), respectively. There was no significant difference between the 1900 machined and the 1050 machined (p=0.2) or (p=0.8) moulded groups. However, there was a significant difference between the 1050 machined and 1050 moulded groups (p=0.05). With machined bearings, increased component size was associated with increased wear rate ($p \leq 0.002$). With moulded bearings, there was no significant relationship between wear rate and component size.

Conclusions: With a fully congruent mobile bearing the linear wear rate is low and is lower with direct compression moulded rather than machined bearings. With machined bearings wear rate increased with component size but surprisingly this was not the case with moulded bearings.

15.

MICROMOTION OF A CEMENTED HINGED TYPE KNEE REVISION SYSTEM WITH MODEL-BASED RSA - preliminary results

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Background: A hinged type revision system is an option in revision total knee arthroplasty when the collateral ligaments are damaged or a large bone defect is present and a condylar revision implant is no option. Due to the hinged design, forces on the implant-bone interface may be different compared to condylar revision arthroplasty designs, with possible consequences for implant loosening. The stability of the fixation of the hinged design has not been studied before.

Purpose/Aim of Study: The goal of this study was to assess the micromotion of a fully cemented hinged type knee revision system, by using radiostereometric analysis (RSA).

Materials and Methods: Twenty patients requiring a fully cemented legion hinge knee system (Smith & Nephew, Memphis, USA) were included. RSA images were taken at baseline, 6 weeks, 3, 6, 12, and 24 months postoperatively. Micromotion of the implant referenced to the markers in the bone of the femoral and tibial implants was assessed using model-based RSA software, using CAD-models of the implant (RSAcore, Leiden, The Netherlands).

Findings/Results: 17 patients are included and at the time of the conference, preliminary results of the 6 months follow-up will be available. Median total translation at 6 months (N=10) was 0.47 (0.08-1.56) mm and median total rotation 0.82 (0.25-1.89)° for the femoral component. For the tibia component the median total translation was 0.20 (0.07–0.46) mm and the median total rotation 0.40 (0.11–0.98)°. Due to the high amount of metal it appeared challenging to have sufficient markers visible on the RSA images.

Conclusions: World-wide this is the first RSA study on a (fully cemented) hinged-type revision TKA. It is important to know the stability of the implant fixation in the bone in order to prevent cases with early aseptic loosening.

16.

An Uncemented 3D-printed versus a Cemented Cruciate-Retaining Total Knee Replacement: 2 years results of a randomized controlled trial using Radiostereometric Analysis

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Background: Although cement fixation is primarily used in Total Knee Replacement (TKR), uncemented fixation is gaining interest as it avoids cement debris and has the potential of achieving lasting biological fixation of the bone to the prosthesis. By 3D-printing an implant, highly porous structures can be manufactured, promoting osseointegration into the implant to prevent aseptic loosening. Aseptic loosening can be predicted by Radiostereometric Analysis (RSA).

Purpose/Aim of Study: To compare the migration of an uncemented 3D- printed to a cemented tibial base plate of a similarly designed TKR up to 2 years follow-up using RSA.

Materials and Methods: Seventy-two patients were randomized to either a cemented Triathlon CR TKR or an uncemented 3D- printed Tritanium Triathlon CR TKR (Stryker, NJ, USA), designed with four additional porous pegs surrounding the stem. RSA and clinical scores were evaluated at baseline and postoperatively at 3, 12 and 24 months follow-up. A mixed-model was used to analyze the repeated measurements.

Findings/Results: The mean Maximum Total Point Motion (MTPM) at 3, 12 and 24 months were 0.36 [95%CI 0.29-0.43], 0.47 [95%CI 0.37-0.56] and 0.54 (95%CI 0.42;0.66) respectively in the cemented group, versus 0.65 [95%CI 0.42-0.88], 0.73 [95%CI 0.49-0.98] and 0.76 (95%CI 0.54 to 0.97) in the uncemented group (p=0.09). One implant in the uncemented and 5 in the cemented group showed >0.2 mm increase in MTPM between 1 and 2 years follow-up. In the uncemented group, 1 patient had a revision due to instability and 1 patient had a liner-exchange 3 weeks postoperatively due to a deep infection.

Conclusions: Overall, there was no difference in MTPM between both groups. The uncemented implants showed higher initial migration, but less patients showed a >0.2mm increase in MTPM between 1 and 2 years follow-up.

17.

Implant migration of a cemented, fixed-bearing medial unicompartmental knee arthroplasty with mid-term follow-up.

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Background: The fixed-bearing Sigma medial unicompartmental knee arthroplasty (UKA) has shown a low 7-year revision rate (5.5-6%) in national registries (National Joint Registry for England Wales and Northern Ireland 2016, AOANJRR 2017). A 2-year radiostereometric analysis (RSA) cohort study with early follow-up showed low implant migration and good clinical outcome (Koppens, Stilling et al. 2017). However, 30% of tibial components showed continuous migration, indicating a risk of loosening.

Purpose/Aim of Study: We now present the mid-term migration of the Sigma UKA.

Materials and Methods: From December 2012 to December 2013, 45 cemented, uncoated, fixed-bearing medial Sigma UKA were implanted in 45 patients (21 male; mean age 63 years; SD 9.7). Stereoradiographs were obtained postoperatively, at 4, 12, 24, and 60 months after surgery. Model-based RSA was used to analyze migration (MTPM) of the tibial components. A sub-analysis will be performed, classifying components as stable (n=26) or continuously migrating (n=11) (Ryd, Albrektsson et al. 1995).

Findings/Results: The cohort showed some initial migration of 0.10 mm (95%CI 0.05; 0.17, $p < 0.001$) between 12 and 24 months, but no statistically or clinically relevant migration was seen between 24 and 60 months. Sub-analyses showed a difference between groups at 12 months, this difference remained stable throughout follow-up. At 60 months the difference between groups was 0.52 mm (95% CI 0.19; 0.71, $p < 0.01$). The continuously migrating group showed no ongoing migration (0.04 mm (95%CI -0.21; 0.37, $p = 0.80$)) between 24 and 60 months.

Conclusions: The Sigma UKA offers low migration of the tibial component at mid-term follow-up. The continuously migrating group migrated until 24 months. Implants stabilized between 24 and 60 months, showing no progressive migration.

18.

Radiostereometric analysis of tibia and patella components from a 3-D printed total knee arthroplasty

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Background: The development of porous metal implants for uncemented fixation in total knee replacement (TKR) has been made possible through additive manufacturing.

Purpose/Aim of Study: The aim of this study was to investigate the fixation of a new 3-D printed tibia and patella.

Materials and Methods: Twenty-nine patients (mean age 64 years, 30% female) who were a candidate to receive uncemented TKR were recruited prospectively in this single cohort study. All patients received a Triathlon® Tritanium® TKR (Stryker, NJ, USA). Patients were followed over the first 24 post- operative months. Tibia and patella fixation was measured with radiostereometric analysis, and patient reported outcome measures were recorded pre- and post-operatively. Implant migration was summarized as maximum total point motion (MTPM).

Findings/Results: A significant improvement in patient function occurred by 3 months ($p < 0.001$). Significant tibia ($p < 0.0001$) and patella ($p = 0.0077$) MTPM occurred over the first 24 months. For both components, the rate of migration was highest over the first 6 weeks. Tibia component migration was significantly different from the previous time point until 6 months, and plateaued thereafter, whereas patella migration plateaued after 6 weeks. Mean difference in tibia MTPM between 12 and 24 months was 0.021 (SD, 0.220), and was statistically within the equivalence bounds of -0.2mm to 0.2mm ($p = 0.0009$). Mean difference in patella MTPM between 12 and 24 months was 0.089 (SD, 0.217). Applying the continuous migration (MCM) threshold for tibias to both components, MCM was found in 5 patients, 3 of whom had MCM in both components.

Conclusions: Osseointegration appears to occur into the highly porous metal of the 3-D printed tibia and patella. Longer follow-up is required to determine if continuously migrating implants will stabilize after 24 months.

19.

Highly cross-linked polyethylene liner shows 10% of the annual wear rate of a conventional polyethylene liner

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Background: Polyethylene cup wear debris can cause osteolysis and late failure of total hip arthroplasty (THA). Introduction of second generation highly cross-linked polyethylene (HXLPE) has been shown to decrease cup wear. There are, however, different manufacturing processes of HXLPE, which can affect the wear pattern.

Purpose/Aim of Study: The purpose of this study was to compare wear pattern of two uncemented cup liners from the same manufacturer, both based on compression molded Ticona GUR 1050 Resin, one made of conventional ultrahigh molecular weight polyethylene (UHMWPE) and the other of highly cross-linked polyethylene (HXLPE) (7.5 MRad gamma-sterilization, melt annealed).

Materials and Methods: 50 patients with osteoarthritis were included in a randomized study, 23 received the UHMWPE liner and 22 got the HXLPE liner. 5 patients got a cemented cup and were excluded. The patients were followed-up for 5 years with repeated RSA examinations (Postop, 3, 12, 24 and 60 months).

Findings/Results: During the first 3 months both liners showed expected creep with a mean proximal head penetration (Y-translation) into the liner of 0.44mm for the UHMWPE and 0.23mm for the HXLPE-liner ($p=0.07$, t-test). Between 3 months and 5 years there was a statistically significant difference in wear ($p<0.0001$, mixed model analysis) with an annual wear of 0.11mm for the UHMWPE-liner and 0.01mm for the HXLPE-liner. No cup was revised or considered loose

Conclusions: The introduction of highly cross-linked polyethylene for the Furlong cups has resulted in a significant decrease of wear. The HXLPE-liner show 10 % of the annual wear rate compared to its precursor.

20.

Comparison of Migration and Kinematics Between Anatomically and Mechanically Designed Total Knee Arthroplasty Implants

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Background: Implant manufacturers continue to introduce new concepts for implant design, which are essential for reaching the goal of a "normal" knee after TKR surgery. The Journey II (Smith & Nephew) has an anatomical design that attempts to mimic the normal knee joint structure to return more natural kinematics to the joint, with emphasis on preserving femoral rollback posteriorly and eliminating paradoxical anterior motion.

Purpose/Aim of Study: This study aims to compare implant migration and joint kinematics with the Journey II TKR compared to a non- anatomically designed implant by the same manufacturer.

Materials and Methods: Recruitment is ongoing for the Journey II TKR cohort, with comparison to an existing prior cohort with a non- anatomically designed TKR (Legion TKR, Smith & Nephew). For the Journey II TKR group, a series of radiostereometric analysis (RSA) images were acquired at 3-months postoperatively at different knee flexion angles, ranging in 20° increments from 0° to 120°. Traditional supine RSA exams were also acquired at 2 weeks and 3 months post-operatively, with ongoing follow-up to 2 years underway in the Journey II cohort. Follow-up is completed in the Legion cohort.

Findings/Results: There was no difference in tibial component MTPM at 2 weeks ($p=0.28$) or 3 months ($p=0.49$) between groups. For contact locations on the medial condyle, there were significant differences at all angles of flexion ($p<0.01$). For contact locations on the lateral condyle, there were significant differences for 0°, 20°, 80°, 100°, and 120° of flexion ($p<0.05$).

Conclusions: Early results suggest that the anatomically designed Journey II TKR provides a decrease in unnatural paradoxical anterior motion. Migration is similar through 3 months to the well-established Legion TKR. Longer follow-up is ongoing.

21.

Similar Proximal Migration but Inferior Stabilization of Cementless Compared with Cemented Dual Mobility Cups in Elderly Coxarthrosis Patients. A Blinded Randomized Radiostereometric and Dual-Energy X-Ray Absorptiometry Study with 24 months follow-up

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Background: Dual-mobility (DM) articulation is a well-proven concept in total hip arthroplasty, but it is currently unknown if cemented or cementless cup fixation is preferential in elderly patients with coxarthrosis (CA).

Purpose/Aim of Study: To investigate the early implant migration pattern of cemented and cementless Avantage dual-mobility (DM) cups in elderly patients with CA.

Materials and Methods: In a prospective patient-blinded randomized clinical trial 60 patients (33 female) with CA were allocated to cemented (n=30) or cementless (n=30) Avantage DM cup fixation. Criteria were age 70 years and older, and T-score above -4. We investigated DM cup migration, systemic and periprosthetic bone mineral density (BMD), and PROMs (HHS, OHS, EQ-5D, VAS hip pain) until 24 months follow-up.

Findings/Results: At 24 months proximal cup migration was 0.11mm (CI95% 0.00-0.23) for cemented cups and 0.09mm (CI95% -0.09-0.28) for cementless cups (p=0.79). But generally, cementless cups migrated more than cemented cups at 12 and 24 months. Cemented cups had no measurable migration from 3 months follow-up, while cementless cups had not yet stabilized at 24 months in all rotations. Cementless cups showed significantly more maximum total point motion (MTPM) at 12- and 24-months follow-up compared to cemented cups in low BMD group (p=0.01). Periprosthetic BMD changes did not correlate to proximal migration in either cup fixation group (p>0.06). PROMs improved similarly in both groups.

Conclusions: We found similar 24-months proximal cup migration in cemented and cementless fixation. However, cementless cups migrated more on absolute measures and had not stabilized at 24 months, whereas cemented cups were stable from 3 months. Cemented fixation of the Avantage DM cup seems safer in elderly patients with preoperative sub-normal systemic BMD.

23.

Validating RSA precision in a low dose biplanar x-ray imager using an in-vivo TKA model

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Background: Radiostereometric analysis (RSA) offers improved motion detection over conventional radiography, but requires specialized equipment and a large reference object. A low radiation biplanar Xray imager (EOS imaging, Paris, France) scans patients in a weight-bearing position, provides calibrated three-dimensional information on bony anatomy, and limits radiation, an asset for serial RSA studies.

Purpose/Aim of Study: RSA in vivo precision values have not been published for this type of imaging system. A poster was presented in Adelaide in 2017 with pilot in vivo data of 13 double exams including 4 with the final protocol. Here we report the results of the ISO standard 15 double exams using the final protocol.

Materials and Methods: At a mean of 5 years post-surgery (range: 1.4-7.5 years), 15 total knee arthroplasty (TKA) participants (mean 67 years at imaging, 12 female, 3 male) with RSA markers implanted were scanned twice in the biplanar imager. The voltage and scan speed were increased compared to standard settings, and an ankle support was added. A small calibration object was attached to the leg to allow for correction of motion artifacts during post-processing. The migration results calculated via RSA analysis by comparing the knee implant position in both exams is used to determine system precision.

Findings/Results: The 95% confidence interval precision was 0.11, 0.04, and 0.15 mm in the x, y, and z planes, respectively and 0.15, 0.20, and 0.14° in Rx, Ry, and Rz.

Conclusions: This precision study has shown an in vivo RSA precision of ≤ 0.15 mm and ≤ 0.20°, well within published uniplanar values for conventional arthroplasty RSA, with the added benefit of weight bearing imaging, a lower radiation dose, and without the need for a reference object during the scan.

24.

Feature Points vs. MTPM approach for the interpretation of a tibial total knee arthroplasty component migration using model-based RSA

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Background: Roentgen Stereophotogrammetric Analysis (RSA) is a highly accurate method to detect in vivo implant migration [1]. But model-based RSA presents a low sensitivity of migration detection if implant is rotated [2, 3]. Migration calculation depends on applied reference point of implant: surface model gravity center (GC), maximal total point motion (MTPM) or so-called Feature Points (FP).

Purpose/Aim of Study: Aim of this study is to assess the sensitivity of different available reference points for migration measurement.

Materials and Methods: A custom-made phantom model was integrated with a uniplanar RSA set-up, simulating migrations for a tibial component. Migrations were simulated in 4 steps, presenting combined translational and separated rotational movements of the tibial implant around each anatomical axis (steps enhancement from 0.2 - 1.5 mm and 0.4 - 3.0 degrees). Migrations were calculated using three different reference points (GC, MTPM, FP).

Findings/Results: Worst case mean migration values (Step 4) of GC are 2.91 mm, 2.40 mm and 2.05 mm for rotations around three anatomical axes and in general below MTPM of 4.52 mm, 3.84 mm and 3.32 mm respectively. For FP mean migration values for one of six available FPs are in the same range as MTPM with 4.49 mm, 3.74 mm and 3.26 mm. However, between all FPs their migration values varying, depending on the direction of simulated rotation.

Conclusions: FPs provide an alternative approach as GC or MTPM for the tibial implant migration. FP enables deeper information for early migration and direction of a tibial component, because at lower simulated migration step the detection is more sensitive and specific in comparison to GC or MTPM, especially for internal rotation. References [1] Kärrholm 1989. AOS 60(4):491-503. [2] Laende et al. 2009. JB 42(14):2387-93. [3] Seehaus et al. 2009. JBE 131(4):041004.

26.

A simulation environment for RSA devices

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Background: RSA is a technique that requires continuous test to assess the reliability of the algorithms. The computer simulation of RSA devises has the opportunity to plan experimental setup and test the algorithms. It is possible to explore situations that are difficult to realize in real experiments and stress the algorithms to evaluate improvements, debugging and performances.

Purpose/Aim of Study: We present a simulation environment, written in MATLAB, that is able to reproduce any RSA setup. Then, we present some test we performed to debug and to evaluate the accuracy of our software.

Materials and Methods: The simulation software was composed by an x-ray source, an x-ray detector, objects in space, and the x-ray beam tracer. The object can be a set of markers, or a bone model, or a prosthesis model. The software creates a virtual scene of the RSA device and the beam tracer returns the images as if they come from a real device. The simulator was used to debug our software, and evaluate its theoretical accuracy in dynamic RSA.

Findings/Results: The simulations found a bug in the marker detection algorithm with particular image noises. The accuracy was (0.092±0.14) mm for tube position and (0.38±0.31) mm/(2.09±1.39) deg for detectors in the direction other than the source-detector direction. In that case the accuracy was of the order of (2.68±3.08) mm for the tube position and (0.16±0.27) mm/(0.75±1.16) deg for detectors. This fact is widely discussed in the literature. The model accuracy was (0.22±0.46) mm/(0.26±0.22) deg. The accuracy remains the same independently from the noise of the images.

Conclusions: This simulation system was able to analyze hidden bugs and help to correct them. This simulator was a first version. Further improvements will be developed to have more and more realistic simulations and explore setups that are closer to reality.

27.

Accuracy and precision of bead-based micro-motion analysis in biplanar pushbroom-projected radiographic scans

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Background: A low-dose biplanar radiographic scanner, EOS, is an emerging tool for 3D measurements in orthopedics. Using EOS for bead-based micro-motion analysis has not yet been investigated and may be clinically feasible due to simpler setup and reduced examination time.

Purpose/Aim of Study: To evaluate reliability of bead-based micro-motion analysis using pushbroomprojected radiographic scans obtained using the EOS Imaging System, and to compare this to a conventional RSA system.

Materials and Methods: A total hip arthroplasty phantom with pelvis and femur was constructed to simulate progressive 3-D micro-motion. The femur with stem and head was mounted on a manual stage to allow micrometer adjusted movement relative to the fixed pelvis with liner and cup. Series of eleven pairs of radiographs with 50 µm movement in-between (10 micro-motions per series) were obtained using the EOS Imaging System; one series of movement along each axis (x, y, and z, relative to the stage), all repeated for two positions of the phantom (isocenter and corner). Custom-built software was used for camera calibration, micro-motion analysis, and calculation of average error and standard deviation. The software will be published under the terms of the GNU General Public License version 3.

Findings/Results: Average error (true-measured) ± SD was 3.1 ± 8.4 µm (med), -2.3 ± 5.2 µm (sup), and 3.3±26.4 µm (post) at the isocenter; and 15.6 ± 20.3 µm (med), 10.8 ± 59.1 µm (sup), and -8.9 ± 12.6 µm (post) at the corner.

Conclusions: Compared to average error ± SD of -16.0 ± 41.0 µm (med), 1.0 ± 30.0 µm (sup), and -0.2 ± 44.0 µm (post) for a conventional RSA system, these results are as reliable when measurements are performed in the isocenter. Further investigations are needed to make it clinically useful.

28.

Model-based Roentgen Stereophotogrammetry (MBRSA) of Radiopaque Polyethylene prosthesis: a Pilot Study

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Background: Ultra-high molecular weight polyethylene (PE) is the articulating surface of the majority of orthopaedic replacements. PE has a low X-ray attenuation, hence the follow-up of the PE prosthesis by direct imaging (X-ray, RSA) is difficult. The radiopacity can be enhanced by diffusing an iodised oil (Lipiodol), for early diagnosis of failure.

Purpose/Aim of Study: To assess the precision of MBRSA to detect radiopaque PE components.

Materials and Methods: This study used 4 Oxford Partial Knee (OPK) bearings (Zimmer-Biomet, UK) with different levels of radiopacity. First, a phantom was used consisting of an OPK tibial tray and a femoral component both rigidly clamped to polycarbonate rods with 6 beads attached to each rod and the OPK bearing positioned between the other OPK components. Second, the tibial tray was removed and the bearing was fixed onto a Sawbone tibia with 6 beads. The phantoms were positioned in a standing RSA setup in front of a carbon uniplanar calibration box (Leiden, NL). Stereo-radiographs of 7 successive poses were acquired from the phantoms. Translational and rotational movements were applied to mimic clinical positioning variation. Zero motion between the markers and the implants was assumed, hence the measured migrations were the experimental errors including the radiopacity level, model accuracy, parts symmetry and the RSA algorithm.

Findings/Results: For the highest level of radiopacity, the largest standard deviation for any translation and rotation was 0.05 mm and 0.46° respectively. The precision level decreased with decreasing radiopacity level. One-way ANOVA showed no difference when comparing this precision with published precision levels of metallic prosthesis and the femoral component of this study ($P>0.05$).

Conclusions: This novel bearing can be analysed with MBRSA with an precision comparable to metal implants.

29.

Validation of in vivo linear and volumetric wear measurement for reverse total shoulder arthroplasty using model-based radiostereometric analysis

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Background: Reverse total shoulder arthroplasty (RTSA) features a cobalt-chrome glenosphere articulating against an ultra-high molecular weight polyethylene humeral liner. A number of studies have evaluated the wear of this configuration through retrieval analysis and simulation studies, though no study has quantified the material loss of well-functioning RTSA implants in vivo.

Purpose/Aim of Study: The purpose of this study was to validate the use of model-based radiostereometric analysis (MBRSA) for in vivo RTSA wear measurement at a single time point using a phantom setup.

Materials and Methods: Six additively manufactured polyethylene inserts were fabricated, one unworn control and five to represent known wear patterns, and individually fit within RTSA components. Each insert was imaged using standard radiostereometric techniques and analyzed using MBRSA. From the position and orientation estimation provided by MBRSA, a micro- computed tomography model of the control insert was virtually placed within the metaphyseal tray. The apparent intersection of the glenosphere into the insert was recorded as wear.

Findings/Results: Our method of measuring in vivo polyethylene wear using MBRSA provided a linear wear depth precision of 0.19 mm and bias of 0.5 +- 0.22 mm, and volumetric precision of 47.0 mm3, with a bias of 46.6 +- 20.4 mm3.

Conclusions: This technique allows for the in vivo measurement of polyethylene wear without the requirement of marker beads or baseline radiographs, expanding the potential for in vivo wear measurements to larger populations and retrospective analysis.

30.

The pitfalls of statistical analysis among RSA studies: would further guidelines help?

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Background: The standardization guidelines have improved the RSA methodology, but they do not cover the statistical analysis of complex RSA data. In recent RSA literature it seems that shortcuts are often taken in the statistical analysis.

Purpose/Aim of Study: To review recent RSA controlled trials (CTs) for practices increasing statistical error. If necessary, provide a basis for discussion and recommendations on how to better approach the analysis of RSA data.

Materials and Methods: Through a literature search on PubMed (National Center for Biotechnology Information, U.S.) a total of 42 CTs, both randomized and non-randomized, focusing on RSA could be identified and retrieved from years 2015 and 2016.

Findings/Results: Out of the 42, 35 studies performed multiple individual statistical tests a priori on the same RSA migration data. Maximum total point motion (MTPM) and total translation/rotation (TT/TR) were used as surrogates for overall implant motion analysis in 27 studies. 21 studies excluded one or more of the available timepoints from the analysis. 16 studies excluded one or more axes from the analysis. Only 10 studies used contemporary multivariate repeated measures methods in the statistical analysis.

Conclusions: Among RSA studies, the current common practice seems to be to analyze all axes of motion individually inflating the risk for type I statistical error. Motion divided on more than one axis at a time is rarely considered in the data analysis. The use of surrogate variables such as MTPM and TT/TR is widespread, but they provide no additional information to the data analysis and serve merely to inflate the risk of type I statistical error. Their use should be discouraged unless clear precedent for their use exists. The hierarchical linear mixed model for repeated measures is capable of modeling and analyzing RSA data properly.

31.

Accuracy and precision of a CT method for assessing migration in shoulder arthroplasty: an experimental study

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Background: RSA is the current standard for measurement of implant migration. A complement could be a technique providing measurements based on CT- scans.

Purpose/Aim of Study: The aim of this study was to validate a computed tomography (CT) technique to measure implant migration in shoulder arthroplasty.

Materials and Methods: A cadaver proximal humerus and a scapula, with tantalum beads incorporated within them, were prepared to accept a short-stemmed humeral component and a two-pegged glenoid component of a total shoulder arthroplasty system. A micrometer and goniometer equipped rig was used to translate and rotate the implant components relative to the respective bone. Double CT examinations were performed for each position and CT motion analysis software (CTMA, Sectra, Sweden) was used to assess these movements. The accuracy and precision of the software was estimated using the rig's micrometers and goniometers as the gold standard. We then did the same estimation of accuracy and precision without the use of the beads in the bone relying solely on the anatomy of the humeral and scapular bone for registration.

Findings/Results: The accuracy ranged between 0.07-0.23 mm in translation and between 0.22-0.71° in rotation with the markers. The accuracy without the use of bone markers were comparable and ranged between 0.10-0.23 mm in translation and between 0.17-0.65° in rotation. The precision ranged between 0.08-0.15 mm in translation and 0.23-0.54° in rotation with the tantalum markers and ranged between 0.07-0.14 mm in translation and 0.21-0.36° without bone markers. The mean effective dose for the CT scans was calculated to be 0.27 mSv.

Conclusions: These results demonstrate that CTMA, with and without the insertion of bone markers per operatively, had a comparable accuracy and precision to RSA. The potential effective dose was slightly higher than RSA.

32.

CT-based micromotion analysis compared to RSA-based: precision and accuracy in patient and phantom hip

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Background: A method which can provide implant migration measurement based on CT-scans would be an attractive complement to the current dual-x-ray- based approach. Any such new method would have to be extensively studied in terms of accuracy and precision and compared to the current golden standard radiostereometry (RSA).

Purpose/Aim of Study: The aim of this study was to give precision estimates for CT-based migration measurement in hip.

Materials and Methods: 10 patients with cemented cups (Exceed ABT, ZimmerBiomet, USA) and tantalum beads inserted into the pelvis had double RSA- measurements as well as double low dose CTmeasurements (0.4 mSv) taken. A phantom pelvis with tantalum beads and a cemented cup with beads had both RSA and CT examinations with the cup in 6 different positions of x, y, z and rotation in x. Each position was recorded with a double measurement. Bland Altman plots were used to present the translation/rotation data. Double measurement precision was estimated for the patient and phantom data.

Findings/Results: One patient had to be excluded from the RSA precision calculation due to marker occlusion. Patient precision estimations were comparable for RSA and CT-based measurements. The translation values for RSA ranged from 0.1 to 0.3 mm and for CTMA from 0.12 to 0.16 mm. For rotation RSA ranged from 0.5 to 1.7 degrees and for CTMA 0.4 to 0.5 degrees. Similar numbers were recorded for the phantom, with the change that RSA rotation precision increased greatly down to 0.13 to 0.32 degrees. For the rotation and translation measurements in the phantom the two methods showed similar readings, as indicated by bland Altman plots.

Conclusions: This preliminary study indicates a good level of agreement between the golden standard in implant measurement, RSA, and a new CT-based alternative, CTMA.

33.

Low dose CT-based implant micromotion analysis: precision data from three ongoing THA studies

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Background: The use of CT to quantify in Vivo implant motion was first studied in the 1990:ies (Reinus et al. 1995, Berger et al. 1996). Our group has studied the topic since 2003 (Olivecrona et al., 2003). Today the method combines compatibility with low-dose CT-settings and the use of standard implants without metal bead markings. Furthermore, no markers are required for the bone and the software is commercially available. Both image acquisition and analysis are easy to adhere to.

Purpose/Aim of Study: This paper gives the clinical precision data of a CT- based implant motion analysis system (CTMA) in three ongoing clinical THA or THA revision studies.

Materials and Methods: A total of 24 double measurements were drawn from three currently ongoing prospective studies; 2 THA and 1 THA revision study; a cemented polyethylene cup (n = 10), an uncemented TOP cup (n = 5), and a acetabular graft cup and a Lubinus cross linked UHWMP polyethylene cup (n = 9). The radiation dose per scan was approximately 0.7 mSv in the two THA studies and 2 mSv in the THA revision study. The implant motion analysis was performed in the software CTMA. Two types of measurements were made; with and without the use of tantalum beads in the bone. For the measurements without beads the bone surface was used.

Findings/Results: The precision in the three studies was 0.09 up to 0.27 mm for translation and 0.10 to 0.32 degree for rotation. The different studies, and the use of metal beads for the reference bone had no discernible impact on the precision.

Conclusions: CTMA could demonstrate precision results comparable to those of the current gold standard RSA. The results showed consistency between the three different hip implants in the three different studies.

34.

Radiostereometric analysis as a limiting case of cone-beam CT reconstruction

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Background: Radiostereometric analysis (RSA) uses two x-ray projections to accurately determine the locations of a sparse distribution of marker beads. What may not be obvious at first consideration is that RSA is fundamentally a limiting case of cone-beam CT reconstruction.

Purpose/Aim of Study: The purpose of this study was to explore the concept that conventional RSA imaging – implemented with two geometrically calibrated x-ray detectors, is really a subset of limited view cone-beam CT (CBCT) reconstruction. In both CBCT and RSA, the x-ray acquisition geometry is carefully calibrated, allowing a mathematical reconstruction technique to "backproject" the rays along known geometric paths. In this study, we demonstrate that conventional RSA, performed with a direct digital x-ray detector, is simply a subset of CBCT reconstruction.

Materials and Methods: Using bone models instrumented with tantalum beads, we acquire up to 200 projection views (DRX3543, Carestream Healthcare) around an anatomical phantom. Intrinsic x-ray camera geometric parameters are determined from a geometric calibration cage.

Findings/Results: Marker bead locations are derived from two views using conventional RSA analysis, and from between 2 and 200 views, using CBCT reconstruction and customized analysis software. We compare the precision of marker location between conventional RSA and limited-view CBCT reconstruction.

Conclusions: In this study, we show that conventional RSA analysis is a subset of the general class of CBCT reconstruction. During the development of new RSA techniques it will be pertinent to take advantage of recent developments in CBCT (including additional view angles and iterative reconstruction) to improve performance. The use of direct digital detectors may allow low-dose cone-beam CT techniques to supplant dedicated RSA, in some applications.

35.

Performance evaluation of a peripheral cone-beam CT scanner with weight-bearing capabilities

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Background: Previous research demonstrated significant differences between supine and weight-bearing conditions in the lower extremity. Recent advances include flat-panel cone-beam CT (CBCT) scanners to study weight-bearing lower extremities. These systems provide superior weight-bearing information about the lower extremity, but may deviate from a perfect rotational trajectory, requiring image corrections before reconstruction.

Purpose/Aim of Study: The objective was to identify imperfections during rotation of a flat-panel ceilingmounted x-ray fluoroscopy system, apply image-based corrections, and validate 3D images.

Materials and Methods: Images were acquired using a ceiling-mounted x-ray fluoroscopy system (Adora RF, Nordisk Røntgen Teknik A/S, Denmark) equipped with a flat-panel detector with a 2688 x 2208 image matrix over a 43 x 35 cm field of view. Image reconstruction requires seven steps that include: (1) characterization of flat-panel detector response, (2) correction for pixel-to-pixel variations, (3) recording gantry position at each x-ray image, (4) characterization of gantry motion during rotation, (5) application of image-based corrections, (6) back-projection to reconstruct 3D images, and (7) validation of image quality using a phantom.

Findings/Results: The ceiling-mounted gantry displays significant, but reproducible imperfections during image acquisitions over a year (2.47 pixels SD). The system uniformity (calculated as the average difference in signal intensity values between the peripheral and central regions) was 31 HU.

Conclusions: We demonstrated that a ceiling-mounted x-ray fluoroscopy system can generate accurate CBCT reconstructions using image- based corrections to account for reproducible imperfections in gantry motion. The ceiling-mounted x-ray fluoroscopy system allows for a larger FOV, compared to current CBCT scanners.

36.

Validation of RSA software and method for Glenoid stability and contact point assessment

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Background: In an ongoing clinical trial we assess the stability of a cemented glenoid shoulder arthroplasty using custom RSA software and novel methods to determine the bearing contact point.

Purpose/Aim of Study: This experimental study was designed to validate the software and assess the precision and accuracy of our clinical study method.

Materials and Methods: A sawbone scapula was implanted with 10 markers medial to the glenoid surface matching our surgical procedure. Eight markers were inserted into the glenoid during manufacturer with sufficient accuracy that they could be used to deduce the CAD model pose and hence bearing surface. 14 markers were glued onto the glenoid and humeral bearing surfaces to test accuracy of contact point determination. The glenoid was fixed to a micrometre device. Accuracy was determined from images of 24 movements in each of the x y and z axes from 0 to 10mm in multiple increments from 0.005 to 2 mm. Rotations were applied similarly from 0 to 8 degrees. Precision was determined from images of repeat repositioning to zero setting with movement of the whole system. Custom RSA software (ABRSAv4.5) was used for image measurement, kinematics and contact point assessment.

Findings/Results: For the glenoid migration accuracy experiment translational bias was less than 0.004mm for all axes with SD less than 0.006mm. Linear bias was less than 0.1%. Rotation had no significant bias and a standard deviation of 0.03deg. Precision (RMS) <0.020mm and <0.05 deg. Measured Glenoid bearing surface was mean 0.07mm SD 0.08mm outside the CAD surface. The head centre was within 0.1mm of the RSA measurement in all images.

Conclusions: With this RSA software Glenoid migration can be measured with high accuracy and precision. Accuracy of the position of the head and bearing surface is sufficient to allow assessment of the contact point.

37.

Fixation and functional outcomes of Exceed cups with porous compared to electrochemically applied hydroxyapatite coating (BoneMaster). A randomized clinical radiostereometry study

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Background: In Denmark 86% of acetabular cups are cementless and 35% of these are coated with hydroxyapatite (HA). HA-coating increases bone ingrowth and early implant fixation. The effect on implant migration is questionable, and it is associated with high polyethylene wear-rates due to third-body wear. BoneMaster (BM) is a new, thin (5µ), evenly distributed, electrochemically deposited, and quickly resorbed hydroxyapatite implant-coating

Purpose/Aim of Study: To evaluate early cup migration and functional outcomes of porous + BM versus porous coated Exceed cups

Materials and Methods: The study design was a prospective patient-blinded, randomized, controlled study. Based on a sample size calculation, 53 non-osteoporotic (pre-op DXA scan) patients with end-stage coxarthritis were block-randomized to either BM or porous coated Exceed cup (ZimmerBiomet). Patients were mean age 64 years (range 55-75). Stems were BM or porous coated Bimetric (ZimmerBiomet). Followup was performed at postop, 3 and 6 months, 1 and 2 years. Effect measures were cup migration measured with radiostereometry and PROMs

Findings/Results: At 2-years follow-up migration in all 6 degrees of freedom were similar between groups (p>0.26). Mean proximal cup migration was 0.20 mm (SD 0.26) for BM and 0.12mm (SD 0.29) for porous coating. Oxford Hip Score (OHS) increased mean 17.3 points (SD 10.9) in both groups from baseline to 2- year follow-up with no difference between groups (p=0.14). At 2-years follow-up OHS (p=0.85, mean 41.6; SD 9.2) and VAS pain (p=0.51, mean 11; SD 23) were similar in the groups. There was one infection and two head/liner replacements related to dislocation and instability

Conclusions: Based on evaluation of cup migration, OHS and VAS pain measures we found similar results for BM and porous coated Exceed cups at 2 years follow-up. Further 5-year evaluation is in progress.

38.

Dynamic RSA and OpenSim: investigation of the joint biomechanic modifications after anterior cruciate ligament reconstruction

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Background: Anterior Cruciate Ligament (ACL) reconstruction is used to restore knee biomechanics after injury. Many studies have tried to support the clinical research by investigating the joint biomechanics after the ACL reconstruction. Among them, the Dynamic RSA seems to be able to achieve the accuracy level to leading the research to the final step.

Purpose/Aim of Study: The goal of this study is to integrate the RSA, with the force platform data and process them with OpenSim to have a sensitive tool able to detect small variations of joint biomechanics.

Materials and Methods: 9 patients with ACL-rupture were evaluated with dynamic RSA, connected to a force platform the day before the reconstruction surgery (PRE) and after 18 months of follow-up (FU). Three different surgical techniques were used: NADB, SB, SBLP. The patients were asked to perform level walking with the ACL injured leg during the x-rays. A force platform, synchronized with the x-rays, acquired the ground force vector. The acquired data were then processed and the results were analyzed in OpenSim.

Findings/Results: Patients were divided by surgical technique and gender. Dynamical evaluations of the knees showed that the Female have a greater abduction moment (2.98 Nm) with respect to males (1.78 Nm). This is true for both PRE and FU and it was reported in the literature. Patients treated with SBLP seems to better control knee movement and reduce the loading acting on the joint during the stance phase of gait (FU-PRE = -1.224Nm). On the contrary, the SB had the worse stability (FU-PRE = 6.463 Nm).

Conclusions: Although at a preliminary stage, the present procedure appears to be a valuable tool for a complete and accurate evaluation of knee joint kinematics and dynamics. Deeper investigations will produce more accurate results on the differences between PRE and FU groups.

39.

A randomized, double-blind, non-inferiority trial, evaluating migration of a cemented vitamin-E stabilized highly cross-linked cup compared to a standard polyethylene cup in reverse hybrid total hip arthroplasty

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Background: Radiosterometric (RSA) studies of vitamin E-doped, highly-crosslinked polyethylene (VEPE) liners show low head penetration rates in uncemented acetabular components. There is no data on cemented VEPE acetabular cups in total hip arthroplasty.

Purpose/Aim of Study: The aim of this study was to evaluate safety of a new cemented VEPE cup, compared to a conventional polyethylene cup regarding migration, head penetration and clinical results.

Materials and Methods: We enrolled 42 patients with osteoarthritis and a mean age of 65 years in a double-blinded, non-inferiority, randomized controlled trial. The subjects were randomized in a 1:1 ratio to receive a cemented cup of either argon-gas gamma sterilized PE cup (controls) or vitamin-E doped highly crosslinked polyethylene (VEPE group), with identical geometry. The primary end point was proximal implant migration of the cup at two years post-operatively measured with RSA. Secondary end points included total migration of the cup, penetration of the femoral head into the cup and patient reported outcome measurements.

Findings/Results: 19 controls and 18 in the VEPE group were analysed for the primary end point. We found a continuous proximal migration of the cup in the VEPE group which was significantly higher with a difference at 2 years of mean 0.21 mm (95% CI 0.05 to 0.37, p=0.013). The total migration was also significantly higher in the VEPE group but femoral head penetration was lower. We found no difference in clinical outcomes between the groups.

Conclusions: At 2 years, this cemented vitamin E cup, although having a low head penetration and excellent clinical results, failed to meet non-inferiority compared to the conventional implant by a proximal migration above the proposed safety threshold of RSA indicative of a slightly increased risk of late aseptic loosening.

40.

RSA and Registries: 1.850.000 total knee replacements with ten year follow-up

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Background: Radiostereometric Analysis (RSA) is an early warning tool to detect unsafe Total Knee Replacements (TKR) with high revision rates for aseptic loosening, and is used for over 3 decades. We hypothesize that this early warning translates into lower revision rates for RSA tested TKR designs compared to non-RSA tested TKR designs.

Purpose/Aim of Study: To compare the revision rate of RSA and non-RSA tested TKR in national registries.

Materials and Methods: All joint registries with online data or reports were eligible. Registries with 10 years follow-up, and information regarding the TKR model and fixation method were included. Revision percentages of RSA tested and non-RSA tested TKR were extracted from the reports and subsequently compared for each registry at 5 and 10 years follow- up. A random effects meta-regression model was used for the analysis.

Findings/Results: Seven registries met the inclusion criteria and approximately 1.850.000 TKR were included. At 5 years follow-up, a lower revision rate of 7% to 36% of the RSA tested TKR was found. Random effects meta-regression showed a risk difference of 0.7% [CI95% 0.2 - 1.1, p=0.001] in revision rate for the registries combined at 5 years in favour of RSA- tested TKR. At 10 years follow-up, the RSA tested TKR had a 7% to 52% lower revision rate. Random effects meta-regression showed a risk difference of 0.9% [CI95% 0.2 -1.5, p=0.01] in revision rate in favour of the RSA tested TKR.

Conclusions: The results of this study show that RSA tested TKR have a lower revision rate than non-RSA tested TKR in a total of 1.85 million TKR from seven national joint registries. Therefore, testing (new) TKR, fixation methods and surgical techniques with RSA leads to better patient care by reducing the revision burden by 7% to 52% at 10 years follow-up, and leading to substantial cost reductions.

41.

Association between early inducible displacement and later continuous migration in cemented and uncemented tibial components

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Background: Migration, and specifically continuous migration between one and two years, is a valuable tool for predicting long-term successful fixation. An alternative RSA- measured metric is inducible displacement: the elastic displacement of an implant relative to the bone, which requires only a one-time visit with unloaded and loaded exams.

Purpose/Aim of Study: This study investigated the association of inducible displacements measured within the first post-operative year and the change in migration from one to two years to determine if early inducible displacements have a role for early screening of cemented and uncemented tibial components in total knee arthroplasty.

Materials and Methods: 122 primary TKAs (86 cemented, 36 uncemented) had migration measured at one and two years and inducible displacements (from single-leg stance) within the first post-operative year (6- 12 months).

Findings/Results: Correlation between early inducible displacement and 1 to 2 year migration was significant, but not strong for all implants ($r = 0.32$, $p < 0.001$), and uncemented components only ($r = 0.37$, $p = 0.03$), but not cemented components ($r = 0.10$, $p = 0.40$). Continuously migrating (>0.2 mm MTPM) components had higher early inducible displacement (mean±SD = 0.34±0.27 mm) than stable components (0.16±0.16 mm, $p < 0.001$). Uncemented continuously migrating components had greater early inducible displacements than stable uncemented components (0.45±0.27 mm and 0.27±0.20 mm respectively, $p = 0.02$), but there was no difference for cemented components.

Conclusions: Screening uncemented implant designs with inducible displacement within the first postoperative year to identify failure to achieve osseointegration may provide valuable information about new implant designs or individual patients, without needing to wait until 2 years to measure continuous migration.

42.

Trabecular Metal Cup-Cage Construct in Immediate Total Hip Arthroplasty for Osteoporotic Acetabular Fractures – A Radiostereometric Analysis

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Background: The management of comminuted, displaced acetabular fractures in the elderly osteoporotic population remains a significant treatment challenge. Advocates of immediate total hip arthroplasty have presented a number of differing technical solutions. Achieving primary stability of the acetabular cup without early migration is challenging and there is no current consensus on the optimum method of acetabular reconstruction

Purpose/Aim of Study: We present clinical results and radiostereometric analysis (RSA) of trabecular metal (TM) cup-cage construct reconstruction in osteoporotic acetabular fractures treated with immediate total hip arthroplasty

Materials and Methods: Between 2011 and 2016, twenty-one acetabular fractures underwent acute total hip arthroplasty with a trabecular metal cup-cage construct. Patient, fracture and surgical demographics were collected. Patients were followed up for a minimum of 24- months. Clinical and patient reported outcome measures were collected at regular post-operative intervals. RSA was used to measure superior migration and sagittal rotation of the acetabular component

Findings/Results: Thirteen fractures were classified as anterior column posterior hemi-transverse, two anterior column, two transverse and four associated both column acetabular fractures. Mean Harris Hip Scores at 24- months was 79 (range 33-98). The mean proximal migration of the acetabular components at 24- months was 0.91mm (range 0.09-5.12) and mean sagittal rotation was 0.52mm (range 0.03–7.35)

Conclusions: To our knowledge this is the first study to accurately measure cup stability following total hip arthroplasty for acetabular fractures. Our promising early clinical and radiological outcomes, assessed by RSA, suggests that this technique may be a good immediate arthroplasty option for acetabular fractures in osteoporotic bone.

43.

Femoral Impaction Bone Grafting at Two-Stage Revision Total Hip Arthroplasty for Infection

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Background: Femoral impaction bone grafting may be used to restore bone stock in revision total hip arthroplasty (THA) and allow use of a standard length cemented prosthesis. This is particularly beneficial in young patients who are likely to require further revision surgery in the future.

Purpose/Aim of Study: This study aimed to assess the use of femoral impaction bone grafting during two stage revision THA for infection.

Materials and Methods: A consecutive cohort of 29 patients who underwent two stage revision (first stage using an interval prosthesis and second stage using femoral impaction bone grafting) were prospectively monitored clinically with patient reported outcomes and radiostereometric analysis (RSA). Femoral stem subsidence at the cement-bone and stem-cement interfaces was measured with RSA. Clinical outcomes assessed were Harris Hip, Harris Pain, and Activity scores. The minimum clinical follow-up was two years.

Findings/Results: Infection was eradicated in 25 patients (87%) after two stage revision. Two of the remaining patients required a further two stage revision THA due to re- infection. Two patients required a washout for infection. An additional patient required head exchange for dislocation. At two year follow-up, the median subsidence at the stem-bone interface was 1.70mm (range 0.31 to 4.98). The majority of subsidence occurred within the cement mantle.The median Harris Hip Score at 2 years was 80 (37-97) and the Harris Pain Score was 44 (10-44). The median pre-operative level of semi-sedentary activity remained unchanged at 2 years.

Conclusions: This study supports the use of femoral impaction bone grafting at the second stage of revision THA for infection. Successful eradication of infection was achieved in the majority of patients. There was minimal stem subsidence and favourable outcomes in terms of pain and function.

44.

Comparison of two roentgen stereophotogrammetry methods for the measurement of hip stem migration in a clinical retrospective study

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Background: Interchangeability of Model-based Roentgen Stereophotogrammetric Analysis (mbRSA) using reverse engineering models has been demonstrated [1,2]. However, marginal loss of accuracy was reported for cranial-caudal rotation measurement of hip stems [1]. A further mbRSA approach uses elementary geometrical shape (EGS) models to measure implant migration.

Purpose/Aim of Study: Aim of this study was to assess the interchangeable applicability of mbRSA-EGS with gold standard marker-based RSA (RSA) [3] for migration measurement of a hip stem in a clinical retrospective study.

Materials and Methods: Migration was detected for n=18 hip stem components (Lubinus, Link, Hamburg, Germany) using RSA and mbRSA-EGS for a 10 years follow up. Migration reference point was corrected, enabled comparison of migration results between two methods [2]. Bland & Altman plot was used to assess interchangeability and limit of agreement (LoA) of the both methods [4].

Findings/Results: The LoA of the two methods for translation measurement was below -0.02±0.34 mm for medial-lateral and cranial-caudal axis, -0.03±0.57 mm for anterior-posterior axis. The LoA for rotation measurement was -0.14±3.85 deg for cranial-caudal axis, which was much greater than that for the other two axes.

Conclusions: This study identified that mbRSA-EGS could be used interchangeable next to gold standard RSA. However, differences on anterior-posterior translational and cranial-caudal rotational migration were large between the two methods, presenting each time an out of plane migration. This was possibly related to the limitation of its working principle using pose-estimation technique [1]. References 1. Seehaus etal.(2009). J Biomech Eng 131(4):041004 2. Hurschler etal.(2009). J Arthroplasty 24:594-606 3. Sundfeldt etal.(2006). Acta Orthop 77(2):177-97 4. Bland and Altman(1986). Lancet 1(8476):307-10.

45.

Early radiostereometric analysis of a 3-D printed uncemented acetabular cup.

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Background: Loosening in total hip arthroplasty (THA) has driven continuous improvement in implant design; however, theoretical changes have not always been clinically effective.

Purpose/Aim of Study: The aim of this study was to investigate the fixation of a second generation, 3-D printed THA.

Materials and Methods: Thirty-three patients (mean age 64 years, 55% female) were recruited prospectively into this single cohort study. All patients received a Trident® II acetabular cup (Stryker, NJ, USA) with Tritanium® highly porous surface for biological fixation. Cup fixation was measured with radiostereometric analysis at 1.5, 3 and 6 months using an immediate post-operative exam as baseline. Cup rotations were calculated using the y symmetry algorithm in Model- based RSA (V 4.11, RSACore, NL).

Findings/Results: At 6 months post-operation, mean proximal translation at 6 months was 0.222 (SD, 0.638) mm, and mean sagittal rotation was 0.310 (SD, 1.956) °. The cup translated significantly in the proximal direction over the first 6 months ($p = 0.0008$), with no significant differences found between adjacent time points after 1.5 months. No significant differences in cup sagittal rotation were found across time points. High proximal migration and sagittal rotation, greater than 1.76mm and 2.53° was measured for one cup.

Conclusions: Osseointegration appears to be occurring into the highly porous metal surface of the 3-D printed cup. Fixation will continue to be followed over the first two post-operative years.

46.

Vitamin E diffused THA liners show less head penetration after 5 years postoperatively compared to HXLPE in a randomized controlled trial

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Background: Long term failure of total hip arthroplasties (THA) is often caused by aseptic loosening. This is associated with increased wear of polyethylene liners, and wear may be reduced by using vitamin E diffused highly cross-linked polyethylene (vitE-HXLPE) liners instead of conventional HXLPE liners.

Purpose/Aim of Study: To compare head penetration between vitE-HXLPE THA liners and conventional HXLPE liners, and between 32 mm and 36 mm femoral heads, measured using radiostereometric analysis.

Materials and Methods: Designed as a factorial trial with 2x2 intervention groups, subjects undergoing THA surgery due to osteoarthritis were randomly assigned to receive vitamin-E diffused HXLPE (E-Poly) or conventional HXLPE (ArComXL) liner with a femoral head size of 32 or 36 mm (4 combined intervention groups). Head penetration and cup migration were measured using radiostereometric analysis at baseline, 3, 12, 24, and 60 months postoperatively. Outcomes were analysed using linear mixed method analyses.

Findings/Results: Liner material affected head penetration. Hence, head penetration was 602 µm [95% CI: 480; 725] for conventional HXLPE and 367 µm [95% CI: 259; 475] for vitE-HXLPE at 5 years postoperative with a between-group difference of 232 µm ([95% CI: 64.3; 401], p = 0.0067) in favour of vitE-HXLPE. Head size did not affect head penetration; within-group change was 447 µm [95% CI: 319; 574] for 32 mm heads and 533 µm [95% CI: 418; 648] for 36 mm heads with a between-group difference of 86 µm ([95% CI: -86; 258], p = 0.33).

Conclusions: Vitamin E diffused HXLPE liners show less head penetration than conventional HXLPE. Head size did not affect head penetration. A lower release rate of wear particles may reduce the risk of aseptic loosening and improve longevity of hip prostheses utilising these liners.

47.

Interrater-reliability of roentgen stereophotogrammetric analysis: A retrospective analysis with multi-raters

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Background: Marker-based Roentgen Stereophotogrammetric Analysis (RSA) is considered as the gold standard to assess implant migration in vivo [1]. Model-based RSA (mbRSA) using elementary geometrical shape (EGS) model allows migration measurement of any implant geometry without the necessity of additional implant markers [2].

Purpose/Aim of Study: Aim of this study was to assess interrater- reliability of RSA and mbRSA-EGS within a clinical study.

Materials and Methods: Clinical RSA data of 18 stems (Lubinus SP II, Link, Germany) and 11 cup (Phoenix, Peter Brehm GmbH, Germany) components were retrospectively analyzed. Three raters performed repeated (n = 3 times) migration analyses with RSA and mbRSA-EGS. Barnhart's [3] method was used to calculate interrater differences, represented by the root-mean-square deviation (RMSD).

Findings/Results: RSA and mbRSA-EGS revealed comparable interrater differences for two implants on all measured translations and rotations (medial- lateral, anterior-posterior), below 0.21 mm and 0.35 deg respectively. However, the interrater difference of mbRSA-EGS (1.05 mm) was much greater than that for RSA of rotation measurements of hip stem component about the cranial-caudal axis.

Conclusions: Both RSA methods reveal minor interrater difference on all translational and most of rotational measurements, whereas mbRSA- EGS showed a large interrater difference on rotational measurement about the cranial- caudal axis, indicating an inferior interrater-reliability on this specific migration measurement of hip stems. This was presumably caused by the limitation of its working principle using pose-estimation technique [4]. References 1. Valstar etal. (2005). Acta Orthop 76(4): 563-72 2. Kaptein etal. (2007). Clin Orthop Relat Res 464: 205-9 3. Barnhart etal. (2007). J Biopharm Stat 17(4): 697-719 4. Seehaus etal. (2009). J Biomech Eng 131(4): 041004.

48.

Implant migration and patient reported hip function two year after primary uncemented THA

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Background: Implant migration patterns up to 2 year after surgery can predict aseptic loosening. Migration and stabilization of the C2 stem and Delta-TT cup (LimaCorporate, Italy) after primary total hip arthroplasty (THA) have not yet been studied.

Purpose/Aim of Study: To evaluate 2-year migration patterns and patient reported hip function after primaryTHA with a C2 stem and Delta- TT cup.

Materials and Methods: A prospective cohort (n=18, age=55±9 years, 13 female) completed RSA X-rays and Hip disability and Osteoarthritis Outcome Score Physical function Short form (HOOS-PS) scores at baseline, 6 weeks, 3, 6, 12, and 24 months post-surgery. We assessed prosthesis migration with Model-based RSA, improvement in HOOS-PS scores, and the relation between both.

Findings/Results: Subsidence of the C2 stem ranged from -0.40-4.91 (median=0.18) mm at 6wk and from - 0.32-5.36 (median=0.22) mm at 2yr. Longitudinal rotation ranged from -3.74-4.54 (median=0.52) degrees at 6wk and from -2.18-3.81 (median=0.47) degrees at 2yr. Translation of the Delta- TT cup was most prominent in cranial direction, ranging from -0.17-0.81 (median=0.13) mm at 6wk and from 0.04-1.50 (median=0.38) mm at 2yr. Rotation of the Delta-TT cup occurred mostly around the AP-axis, ranging from - 0.74-4.83 (median=0.22) degrees at 6wk and from -0.40-6.40 (median=0.33) degrees at 2yr. HOOS- PS scores improved from 49.0±19.5 pre-surgery to 8.33±7.92 at two year follow up ($p<0.001$). No significant correlations were observed between implant migration and patient reported hip function at 2 year (all $R2<0.14$ and $p>0.16$).

Conclusions: Migration occurred mainly in the first six months, which is in line with expectations and seems promising for long-term implant survival. Patient reported hip function substantially improved and was not associated with implant migration at 2-year follow up.

49.

No effect of liner type on migration patterns and patient-reported hip function up to two years after primary Total Hip Arthroplasty (THA) using an innovative uncemented Trabecular TitaniumTM cup

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Background: Ceramic liners might negatively affect early stabilization of uncemented acetabular cups due to higher stiffness. However, bone ingrowth capacities of highly porous Trabecular TitaniumTM might compensate for this effect.

Purpose/Aim of Study: To assess the effect of liner type on migration patterns of the Delta-TT cup (LimaCorporate, Italy) and patient-reported hip function in patients up to two years after primary THA.

Materials and Methods: Patients undergoing uncemented primary THA with a Delta-TT cup were randomized to a polyethylene (n=25) or ceramic (n=28) liner. RSA X-rays and patient-reported outcome measures (PROMs) were collected at baseline, 1.5, 3, 6, 12 and 24 months after surgery . Model-based RSA was used to calculate 3D migration of the cup with respect to the bone. Differences in migration patterns and PROMs between groups were analysed using repeated measures ANOVA.

Findings/Results: We observed no significant differences in migration patterns between liner types throughout the two-year follow-up period (all p for interaction >0.18). Regardless of liner type, Delta-TT cups showed initial migration, with mean translations below 0.55 mm and mean rotations below 0.44 degrees. Individual migration patterns showed that almost all cups stabilised within 6 months. Both groups experienced similar improvement in HOOS-PS, OHS and EQ-5D scores over time (all p for interaction > 0.11).

Conclusions: Ceramic liners do not seem to negatively affect migration patterns or patient-reported hipfunction of the Delta-TT cup. Regardless of liner type the cup stabilises in about 6 months, which is promising for long-term survival.

50.

Total Hip Arthroplasty Surgical Approach and Implant Design: Effects on Patient Function, Patient Activity, and Implant Migration

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Background: There is increasing pressure for rapid recovery care pathways following THA. The increasing adaptation of the muscle sparing Direct Anterior (DA) approach relative to the more invasive Direct Lateral (DL) approach can be seen as a response to these changes. Femoral implants have been designed with the intention of enhancing patient function and implant stability with the DA approach.

Purpose/Aim of Study: This study aims to evaluate the effects surgical approach and implant design have of patient function, patient activity, and implant migration.

Materials and Methods: Patients with unilateral hip OA who were undergoing primary THA surgery were recruited pre-operatively to participate in this prospective randomized clinical trial. Selection for surgical approach was expertise based and all patients were randomized to receive either a collared or collarless cementless femoral stem. Patients underwent RSA exams at <24 hours and 2, 4, 6, and 12 weeks postoperation, with further follow-up currently ongoing to 2 years. Patients completed an instrumented timedup- and-go (TUG) test using wearable sensors at each visit, and logged their steps using Fitbit activity trackers.

Findings/Results: The DA group had significantly better function at 2 weeks ($p<0.01$) and 4 weeks ($p=0.02$). The DA group also had significantly greater activity at 6 weeks ($p=0.03$) and 12 weeks ($p=0.01$). The collared implant subsided less than the collarless implant from <24 hours to 2 weeks post-operatively ($p=0.04$). Migration was lower in the DL group ($p<0.01$).

Conclusions: Early results suggest that the DA surgical approach results in earlier patient functional recovery and activity compared to the DL surgical approach, but might also result in greater femoral stem migration that is partially alleviated by a collared design.

51.

Three Year Wear and Migration of a Dual Mobility Hip Cup

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Background: The dual mobility design for acetabular components is intended to reduce the risk of dislocation and potentially increase range of motion, but the wear pattern of this design is unclear and may have implications in implant fixation.

Purpose/Aim of Study: This study assessed cup fixation polyethylene wear by measuring implant migration and proximal femoral head penetration.

Materials and Methods: Thirty subjects were recruited in a consecutive series prospective study and received dual mobility uncemented acetabular components with mobile bearing highly cross-linked polyethylene liners, cemented or uncemented femoral stems, 28 mm femoral heads. The femur, acetabulum, and non-articulating surface of the liner were marked with tantalum beads. RSA exams were performed immediately post- operatively and at 6 weeks, 3, 6, 12, 24, and 36 months. Mobile bearing motion was assessed under fluoroscopy for a single case during loaded and unloaded conditions.

Findings/Results: Twenty-nine subjects (17 female) proceeded to surgery. Subjects were 63±11 years of age with BMIs of 28±4.7 kg/m2. Cup migration reached 0.16±0.31 mm of proximal translation and 0.29±1.03 degrees of sagittal rotation at three years. Wear was 0.18±0.30 mm of proximal femoral head penetration from 0 to 3 years. The mean wear rate from 1 to 3 years was 0.02 mm/year. The fluoroscopic case study demonstrated visible motion of the mobile bearing during hip rotation tasks.

Conclusions: The overall migration of the cup was low and demonstrated favorable patterns suggesting low risk of aseptic loosening. Wear rates are also within the expected range of <0.05 mm/year for highly crosslinked polyethylene. The combination of low subsidence and low sagittal rotations of the cup, and low wear of the polyethylene are favorable predictors of good long-term performance.

52.

A Review of Acetabular Component Migration Measured using Radiostereometric Analysis following Revision Total Hip Arthroplasty

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Background: Registries are commonly used to assess the performance of implants used at primary total hip arthroplasty (THA). However, assessing implants used at revision THA is more difficult due to the variability in bone quality, the number of previous revisions and differences in surgical technique across institutions.

Purpose/Aim of Study: The aim of the review was to identify all studies of acetabular components used at revision THA that had prospectively measured migration using RSA. The secondary aim was to determine if increased early migration was associated increased rates of later loosening.

Materials and Methods: A systematic search was performed on Pubmed, Scopus and Embase. The review included RSA studies that measured the migration of acetabular components following revision THA. Exclusion criteria included patients that had a reconstruction with a cage where the acetabular component is not in contact with host bone; reconstructions following radiotherapy and tumour excision; or revision of hemiarthroplasties.

Findings/Results: Fifteen publications including 16 different patient cohorts were identified in the review. Ten different acetabular components were used in these cohorts. Seven cohorts reported a 2 year mean migration which was found to correlate with the re-revision rate for loosening (R2=0.76, p=0.02). Eight cohorts using a cemented component reported a higher 2 year mean migration when compared to seven cohorts that used an uncemented component (adjusted mean 1.43mm vs. 0.53mm, p=0.013).

Conclusions: All cohorts reported a higher mean migration at two years than that previously recommended for primary acetabular components (Pijls et a 2012). Cemented and uncemented acetabular components migrate differently and there was a positive relationship between the amount of two year proximal migration and the rate of aseptic loosening.

53.

Can a medially stabilized TKA design approach a natural knee kinematics?

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Background: It is known that to obtain a stable kinematics is the most challenging goal to achieve after TKA. The femoral surface of a medially stabilized (MS) TKA is spherical on the medial side in the first degrees of flexion, thus the radius closes slightly. The medial part of the polyethylene surface is more congruent respect to the medial condyle, while the lateral one is flat anteroposteriorly. These features would theoretically provide an anterior-posterior stability and a greater rotation of the medial condyle.

Purpose/Aim of Study: To describe the in vivo kinematics of the knee after MS Fixed Bearing TKA (GMK Sphere(TM) Medacta International AG, Castel San Pietro, Switzerland) using Model Based dynamic RSA.

Materials and Methods: A cohort of 14 patients (mean age 70,7 yr) was evaluated at 9 months of follow up after surgery. The patients performed two motor tasks: a sit-to-stand and a lunge. Kinematical data were evaluated using Grood and Suntay decomposition and Low point method. Data were related to the flexion angle versus internal-external, varus-valgus rotations and antero-posterior translations of the femur with respect to the tibia.

Findings/Results: During sit-to-stand a clear medial pivot from 80° until full extension was observed. A slight internal rotation of the femur was evaluated during the whole movement. Concerning the lunge, from the beginning to the end of the bending, the condyles make a posterior translation simultaneously, with an external rotation. During the extension phase, an anterior translation, a slight medial pivot and an internal rotation were observed.

Conclusions: The kinematic data of the investigated prosthesis are similar in both motor tasks. This behaviour reproduces a medial pivot, as in the native knee joint.

54.

Measurement of knee kinematics during examiner applied pivot-shift test. A dynamic radiostereometric cadaver study

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Background: Rupture of the Anterior cruciate ligament (ACL) is one of the most common ligament injuries in the knee and may be associated with damage to extracapsular knee rotation- stabilizing structures, such as the anterolateral ligament (ALL).

Purpose/Aim of Study: This study investigated the effect of the ALL on knee rotational stability during an examiner applied pivot-shift test.

Materials and Methods: Six cadaver knees were tested in five successive ligament stages: Intact, ACL lesion, ACL+ALL lesion, ACL reconstruction and ACL+ALL reconstruction. Every ligament stage was recorded with dynamic radiostereometry during a repeated pivot- shift test performed by an experienced surgeon. The pivot-shift movement was evaluated using two parameters: A) the curve area between the flexion and extension phase of the tibial rotation as a function of knee flexion angle. B) the anterior-posterior excursion length of the medial contact point. For statistics, a mixed model was used, which took into account repeated measurements of the specimens, pairs, and stages.

Findings/Results: A significantly increased curve area and medial excursion path was found when transecting the ACL ($p<0.02$) and ALL ($p<0.01$). The ACL reconstruction decreased both parameters ($p<0.02$) but the following ALL reconstruction did not decrease the parameters further, ($p>0.75$) and was significantly different as compared to the ligament intact stage ($p<0.03$).

Conclusions: In conclusion, ALL increases the pivot-shift in the ACL deficient knee, but ALL reconstruction in addition to ACL reconstruction did not reestablish a native pivot-shift.

55.

Kinematic analysis of a cruciate-retainig TKA during the sit to stand

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Background: Cruciate-retaining total knee arthroplasty (CR-TKA) is one of the principal techniques used to replace the osteo-arthritic knee joint. As far we know, a less number of studies based on dynamic RSA or fluoroscopy evaluated the kinematic of the investigated prosthesis with controversial results.

Purpose/Aim of Study: This work presents a kinematic evaluation of a CR-TKA (GEMINI(R) SL(R) Mobile Bearing, Waldemar LINK GmbH & Co. KG, Hamburg, Germany) design using Dynamic RSA. The aim of this study is to better understand the in vivo kinematics of knee joint after this CR MB TKA design.

Materials and Methods: A cohort of 15 patients was evaluated at 9 months of follow up, after the implantation. The mean age of patients was 74.8 (range 68-83) years. The patients were asked to perform a sit-to stand motor tasks: from the sitting position, the patient stands up. Kinematical data are evaluated relating the flexion angle versus Internal-External rotations, Varus-Valgus rotations and Antero-Posterior
translations of the femur respect to the tibia using the Grood and Suntay decomposition. Moreover, lowpoint contact areas was studied.

Findings/Results: From maximum of 80° knee flexion, an anterior femoral translation was observed. From 80° knee flexion to 60°, kinematic pattern indicates a slight lateral pivot. From 60° knee flexion to maximum extension, the kinematic pattern is a bi-condylar rollback where both condyles moved backward in parallel. During the whole movement, an internal rotation trend was observed.

Conclusions: The observed kinematics is not similar to the normal knee and it is different from several expects. The found results are in agreement with some other works in the literature and not with other. The debate is still open and further investigations are in progress.

56.

Can different TKA design influence postural stability during a lounge?

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Background: Good clinical and functional outcomes after Total Knee Arthroplasy (TKA) are the best goal to achieve after surgery. During the TKA implantation the sacrifice of several anatomical structures, which contain important proprioceptors, results in balance dysfunction and risk of falls. A less number of studies evaluated the knee kinematics after TKA using Dynamic RSA match with a balance evaluation.

Purpose/Aim of Study: To evaluate if the kinematics of different TKA designs result in a different postural control using dynamic RSA and wearable sensor.

Materials and Methods: A cohort of 15 patients with three different TKA designs was evaluated at 9 month of follow up after surgery. Each patient performed a lunge with the operated knee. Dynamic RSA and wearable sensor, applied on a patients' sternum, were used simultaneously to evaluate the knee kinematics and postural stability.

Findings/Results: The Kinematics of the three different prosthesis designs showed results about Internal- External, Varus-Valgus rotation and Antero-Posterior translation, in according to our past studies and to the literature. Concerning the postural stability, the trunk displacement respect to the medial axis resulted wide in each side of all the patients. Moreover, a similar trend of the body displacements on the frontal plane was found.

Conclusions: Although three TKA designs with different features were evaluated, no differences in terms of postural outcomes were recorded. The use of Dynamic RSA simultaneously with a postural evaluation system, could be useful to better understand the knee kinematics and the postural control in patients with TKA.

57.

Dynamic radiostereometric analysis for pre- and postoperative evaluation of range of motion in the femeroacetabular impingement hip joint

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Background: Dynamic RSA (dRSA) enables precise non- invasive 3D motion-tracking of bones. Hereby, the biomechanical effects of arthroscopic cheilectomy and –rim trimming (ACH) can be evaluated in patients with femoroacetabular impingement (FAI).

Purpose/Aim of Study: The aim of this study was to investigate the pre- and postoperative range of motion (ROM) and CT bone volume removed after ACH.

Materials and Methods: 13 patients were included. The patients were CT-scanned and CT-bone models were created. Preoperative dRSA recordings were acquired at 5 frames/sec during flexion to 90°, adduction to stop and internal rotation to stop (FADIR). ACH was performed, CT and dRSA was repeated 3 months post-operativly. dRSA images were analyzed using automated AutoRSA (NRT, Denmark) software. Hip joint kinematics before and after ACH were compared pairwise. The BV was quantified and compared to postoperative ROM.

Findings/Results: Mean internal rotation was 11.9° before and 8.4° after ACH surgery (p=0.34, Δ3.5°, CI: - 3.8°;10.7°). Adduction was 11.6° before and 11.1° after ACH surgery (p=0.79, Δ -0.5°, CI: -4.4°; 3.4°). Mean flexion angles during dRSA tests were 79.9° before and 77.7° after ACH surgery (p=0.44, Δ 2.2°, CI: -3.4°; 7.8°). No difference in subluxation, of the femoral head in the acetabulum, along the x-, y- and z-axis was observed (p>0.05). The BV was 406-1783 mm3 and was not correlated to ROM.

Conclusions: No change in ROM was observed after ACH in 11 FAI patients at 3-month follow-up. This could indicate that the positive clinical effects of ACH are not brought by increased ROM but due to reduction in labral stress and cartilage pressure during end-range motion. Due to short follow-up, the ROM might also still be influenced by postoperative sequelae. The 1-year follow- up data will be ready for presentation at the conference providing more evidence.

58.

In vivo kinematics of a Fixed and Mobile Bearing TKA in the same patient: a case report

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Background: Total knee arthroplasy (TKA) polyethylene can be subdivided in two design groups: fixedbearing (FB), where the polyethylene tibial insert is locked with the tibial tray, and mobile-bearing (MB), which facilitate movement of the insert relative to the tray.

Purpose/Aim of Study: To describe in vivo kinematics of a PS MB TKA and a PS FB TKA implanted in the same patient using Model Based dynamic RSA.

Materials and Methods: One patient (72 yo) with the implantation of both insert designs was evaluated at 2 years of follow up after surgery. The FB was implanted in the left knee, the MB in the right one. Dynamic RSA was used to evaluate the kinematics while the patient performed a sit-to-stand. Kinematical patterns were evaluated using Grood and Suntay decomposition and Low point Method. Data were related to the flexion angle versus Internal-External (IE), Varus- Valgus (VV) rotations and Antero-Posterior (AP) translations of the femur with respect to the tibia.

Findings/Results: During the sit-to-stand of the FB, from 80° to 30° a slight lateral pivot was observed, then both condyles moved simultaneously forward until full extension. The MB design shows a wider lateral pivot during the whole movement, with a greater anterior translation of both condyles. Concerning IE rotations, FB design made an internal rotation trend during the whole movement. On the contrary the MB shows an internal rotation from 80° to 40°, then an anterior translation was observed until full extension. VV rotations of both designs didn't show any significative pattern, in according with a correct soft tissues balancing.

Conclusions: A different kinematic result between FB and MB designs was found. Despite of that, the clinical outcome of our patient was excellent for both knees. The theoretical advantages for MB design have not been demonstrated by any outcome studies.

59.

In-Vivo Kinematic Evaluation Of A New Design Total Knee Arthroplasty Using Dynamic RSA

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Background: TKA posterior stabilized (PS) is the best surgical choice when the posterior cruciate ligament is unfunctional. The central cam stabilizes the anterior-posterior translation. Moreover, the multi-radius feature of the investigated implant makes a smooth transition throughout the range of motion and minimizes the anterior movement.

Purpose/Aim of Study: The aim of this study is to describe the in vivo kinematics of the knee after PS Rotating Platform TKA implantation Attune (TM) Knee System, DePuy Synthes, J&J, Warsaw, IN, USA) using dynamic RSA.

Materials and Methods: A cohort of 8 patients (mean age 67.6 yr) was evaluated at 9 months of follow up after the TKA. The patients were asked to perform a lunge: from the neutral position, the patient makes a step, then flexes, and return to the stand position. Kinematical data were evaluated relating to the flexion angle versus Internal-External rotations, Varus-Valgus rotations and Antero-Posterior translations and and low-point contact areas of the femur with respect to the tibia, using the Grood and Suntay decomposition.

Findings/Results: During the lunge phase, from 20° to 40° of knee flexion, an internal rotation of about 3° was evaluated. Then, from 40° to 80° an external rotation was observed. During the flexion, from 20° to 80° the kinematics indicates a posterior translation of the femur respect to the tibia. Then it turns to an anterior translation during the extension. Low Point kinematics showed a slight medial pivot from 50° to 55° of knee flexion.

Conclusions: The kinematical results obtained with dynamic RSA showed that this prosthesis model is not affected by the paradoxical anterior translations during lounge motion task reported by other designs. Further studies are needed to evaluate the impact of different TKA designs on clinical results.