9th International RSA Meeting

Vancouver, Canada

June 10-11, 2025

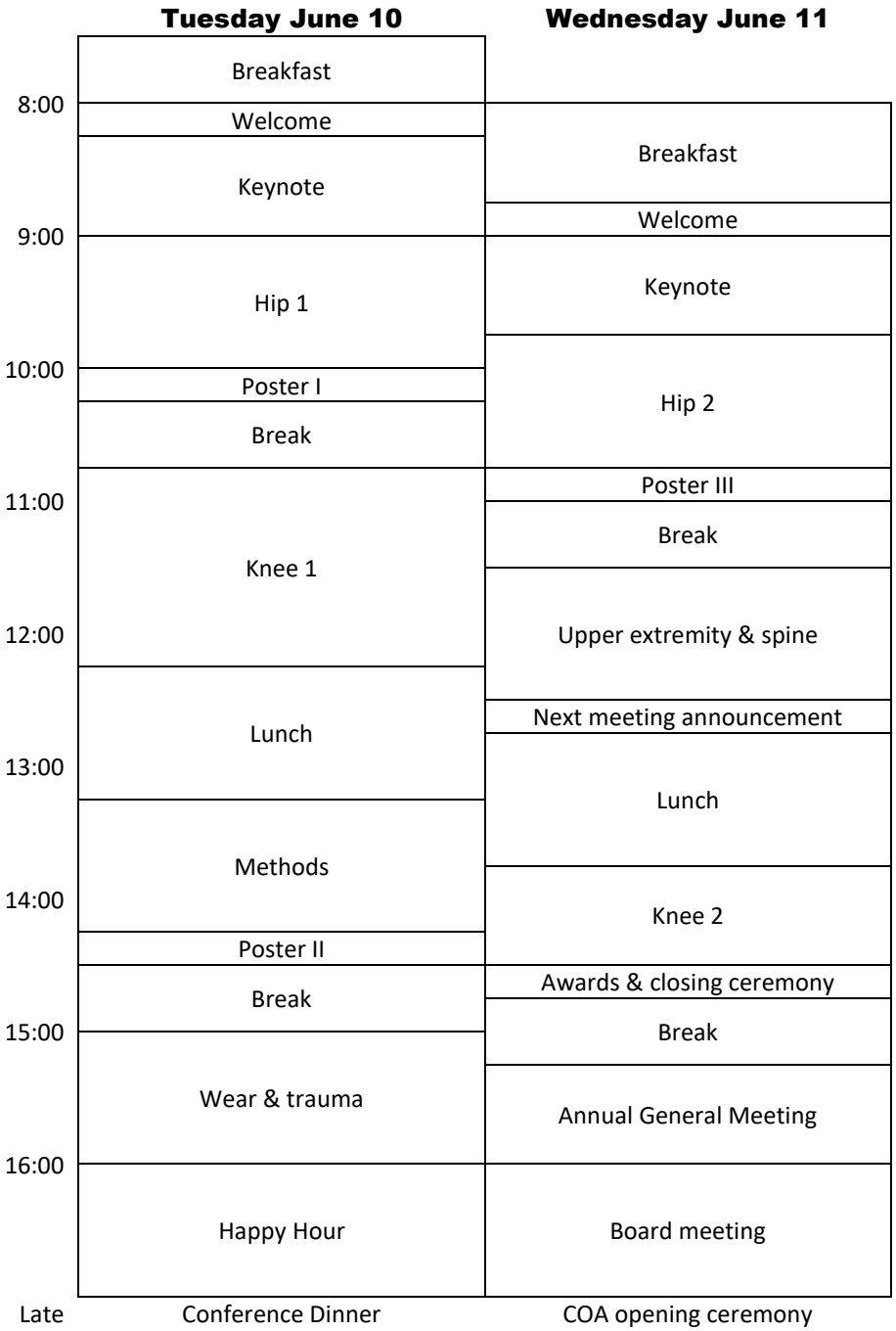
Program

Program at a glance

The conference venue is the Vancouver Convention Centre East (Canada Place). Breaks and meals will take place in the South Foyer, sessions will be held in Room 1, both on the second floor of the East building

Conference badges can be picked up 7:00-17:00 on June 10 in the South Foyer.

ePosters are available to browse during all breaks.



Welcome

Dear attendees,

We are happy to welcome you back to Canada, a mere 6,000 km away from were the first International RSA meeting was held in 2009. We have seen transformative change in our field over the last 15 years and we see this by the great and varied work that will be presented over the next two days. We have programmed ample time for breaks to network and socialize, including during our sunset conference dinner in iconic Stanley Park.

The Vancouver Convention Centre is situated on the ancestral, unceded territories of the Musqueam, Squamish, and Tsleil-Waututh peoples. We gratefully acknowledge and appreciate the privilege to operate on these lands, and we recognize the enduring presence and stewardship of these peoples.

We enjoyed the rapid-fire poster sessions from the last conference and programmed these in this session as well to allow each presenter two minutes to highlight their results before coffee breaks. The full ePosters are available to view at each break and we encourage attendees to ask their questions to the presenters during these breaks. We also follow the Canadian Orthopaedic Association meeting standard in which there is a longer discussion after every three talks, rather than brief questions after each individual presentation.

We hope you enjoy the conference and everything Canada has to offer.

On behalf of the organizing committee,
Trevor Gascoyne

Organizing committee

- Trevor Gascoyne, Chair
- Brent Lanting
- Elise Laende
- Matthew Teeter
- Christiaan Righolt

On behalf of the Canadian RSA Network

RSA Network

Sponsors

Gold sponsor

SECTRA

Silver sponsors

J&J MedTech

Smith+Nephew

Bronze sponsor

GE HealthCare

Halifax Biomedical Inc.

Lunch sponsor

HIP INNOVATION TECHNOLOGY

Program Monday June 9, 2025

18:00-close Reception Steamworks Brewpub 375 Water St.

Program Tuesday June 10, 2025

7:15-8:00	Breakfast	South Foyer
8:00-8:15	Welcome & opening ceremony	Room 1
8:15-9:00	Keynote	Room 1

Moderator: Matthew Teeter

Sprinting towards a clinically practical, workflow efficient approach to quantify dynamic joint motions
Scott Banks

9:00-10:00 Hip 1 — Room 1

Moderators: Brent Lanting & Trevor Gascoyne

9:00	P1	**Validation of early RSA acetabular implant migration thresholds for long-term aseptic loosening with international registry studies** *Chan Hee Cho*
9:07	P2	**Estimating the migration patterns of acetabular implants with the use of early RSA data** *Chan Hee Cho*
9:14	P3	**Migration in total hip arthroplasty with G7 BiSpherical acetabular system combined with the Global Tissue Sparing (GTS) stem: a radiostereometric study with 5 years of follow-up** *JH Pasma*
9:21		**Discussion**
9:30	P4	**Migration in total hip arthroplasty with the Maxera Acetabular System compared to the Allofit Acetabular Cup System: a radiostereometric study with 5 years of follow-up** *JH Pasma*
9:37	P5	**Custom triflange acetabular components result in a stable fixation in majority of revision hip arthroplasty cases with large acetabular bone defects. Preliminary short-term RSA results of 15 multicenter cases.** *D Broekhuis*
9:44	P6	**Quantifying component impingement in total hip arthroplasty: In vivo analysis of neck-liner distances during activities of daily living** *Matthew Teeter (Shahnaz Taleb)*
9:51		**Discussion**

10:00-10:15 Poster session I — Room 1

Moderators: Brent Lanting & Trevor Gascoyne

10:00	E1	**Model-based wear measurement on plain radiographs enables early monitoring of TKA inlay wear** *C Emonde*
10:02	E2	**Comparison of the in vivo stability of 2 cementless TKA designs using CT micromotion analysis - A randomized controlled trial** *Frank-David Øhrn,*
10:04	E3	**The importance for precision to harmonize CT measurements in migration studies. A randomized controlled clinical trial** *E Kristoffersson*
10:06	E4	**Five Year Follow-Up of a Gap Balancing and Measured Resection Surgical Technique with Radiostereometric Analysis and Weight-Bearing Computed Tomography** *Rebecca Hext*

10:08	E5	**Longitudinal assessment of impingement risk following total hip arthroplasty through the direct anterior approach** *Matthew Teeter (Shahnaz Taleb)*

10:15-10:45 Coffee break — South Foyer

10:45-12:15 Knee 1 — Room 1

Moderators: Petra Heesterbeek & Maaike de Bondt

10:45	P7	**Five-year migration of uncemented femoral components in total knee arthroplasty with either highly cross-linked or conventional polyethylene inserts: a blinded randomized controlled trial using radiostereometric analysis** *Ruud de Ridder*
10:52	P8	**Tibial Component Migration and Metal Ion Release of a Coated and Non-Coated Implant Design** *Rebecca Hext*
10:59	P9	**Contact Kinematics and Tibial Component Migration of a Medial-Pivot Total Knee Arthroplasty Design** *Rebecca Hext*
11:06		**Discussion**
11:15	P10	**What is the long-term pattern of migration of the individual implant in cemented and uncemented TKA?** *Radoslaw Wojtowicz*
11:22	P11	**Time-zero motion is not related to the bone mineral density in well-fixed uncemented tibial baseplates** *Fernando J Quevedo Gonzalez*
11:29	P12	**Tibial component migration and inducible displacement for cruciate retaining and posterior stabilized implants in cemented total knee arthroplasty** *Elise Laende*
11:36		**Discussion**
11:45	P13	**Equal tibial and femoral component fixation of a mobile-bearing and fixed-bearing lateral unicompartmental knee arthroplasty with 5-years follow-up** *Andreas Bidstrup Hovmark*
11:52	P14	**The preoperative gait pattern is associated with migration of total knee arthroplasty - an exploratory radiostereometric study with 2 years follow-up** *Emil Toft Petersen*
11:59	P15	**Severe knee osteoarthritis increases the risk of continuous migration of cementless tibial implants. A prospective clinical cohort RSA study of 928 patients** *Johannes Marsay Dal*
12:06		**Discussion**

12:15-13:15 Lunch — South Foyer

13:15-14:15 Methods — Room 1

Moderators: Matthew Teeter & Bart Kaptein

13:15	P16	**Comparison of Two CT-based Radiostereometric Analysis Systems** *Maaike R. de Bondt*

13:22	P17	**CT-based radiostereometric analysis (CT-RSA) Validation: in vivo agreement between Volumetric Matching Micromotion Analysis (V3MA) and RSA for a femoral prosthesis in TKA** *Jessie Robertson*
13:29	P18	**Dose reduction does not impact precision of CT-RSA in total knee arthroplasty – a clinical trial** *Fredrik Bru*
13:36		**Discussion**
13:45	P19	**Evaluation of migration analysis with AI-based CT-RSA and preoperative 3D-planning in total hip arthroplasty** *Albin Christensson*
13:52	P20	**A single CT is enough for CT-based radiostereometric analysis** *Emil Toft Petersen*
13:59	P21	**VoluMetric Matching Micromotion Analysis (V3MA) enables accurate quantification of implant inducible displacement between repeat CT examinations** *Bart Kaptein*
14:06		**Discussion**

14:15-14:30 Poster session II — Room 1

Moderators: Matthew Teeter & Bart Kaptein

14:15	E6	**CT-based radiostereometric analysis (CT-RSA) Validation: in vitro precision of Volumetric Matching Micromotion Analysis (V3MA) and impact of image segmentation for a femoral prosthesis in TKA** *Jessie Robertson*
14:17	E7	**2y CT-RSA results in revision total hip patients – the PROUD study** *Olof Sandberg*
14:19	E8	**Preliminary Results of the Accuracy of CT-RSA of the TOUCH® Dual Mobility TMC Prosthesis: migration measurements in an anatomic specimen study** *R. Oomen*
14:21	E9	**Migration in unicompartmental knee arthroplasty with the Persona® Partial Knee: a radiostereometric study with 5 years of follow-up** *JH Pasma*
14:23	E10	**CT-RSA is a suitable replacement for RSA in evaluating migration of tibial implants – phantom study of accuracy** *Lars Engseth*
14:25	E11	**The accuracy and precision of CT-RSA in joint arthroplasty: a systematic literature review** *Bart Kaptein (Nienke de Laat)*

14:30-15:00 Coffee break — South Foyer

15:00-16:00 Wear & trauma — Room 1

Moderators: Trevor Gascoyne & Stephan Rohrl

15:00	P22	**Wear in total hip arthroplasty with the Regenerex cup: a radiostereometric study with 10 years of follow-up** *JH Pasma*
15:07	P23	**The effect of implant, surgical and patient factors on the long-term wear of highly cross-linked polyethylene liners** *Stuart Callary*

15:14	P24	**The influence of surgical approach on acetabular cup migration and wear in total hip arthroplasty – a multi-centre radiostereometric analysis study** *Trevor Gascoyne (Edward Vasarhelyi)*
15:21		**Discussion**
15:30	P25	**Total hip arthroplasty for acute acetabular fractures through the replace-in-situ philosophy: radiographic assessment of cup stability** *John Abrahams*
15:37	P26	**Enhancing torsional stability with interlocking plates in undisplaced femoral neck fractures – a randomized controlled trial using radiostereometric analysis** *Magnus Hogevold*
15:44		**Discussion**

16:00-17:00 Happy hour — South Foyer

Catch up with old friends and make new friends to discuss your RSA questions, difficult analyses, challenges, and anything else that comes to mind.

18:30-22:30 Conference dinner — Teahouse in Stanley Park

The Teahouse is located at 7501 Stanley Park Drive, Vancouver at Ferguson Point in Stanley Park. The restaurant is 4.5 km from the conference centre and can be reached by walking (50 minutes), taxi and ridesharing services.

18:30	**Drinks**
19:30	**Dinner**
21:00	**After party**

Program Wednesday June 11, 2025

8:00-8:50	Breakfast	South Foyer
8:50-9:00	Welcome	Room 1
9:00-9:45	Keynote	Room 1

Moderator: Elise Laende

Health Data and Multi-jurisdictional Research Collaborations *Kim McGrail*

9:45-10:45 Hip 2 — Room 1

Moderators: Christiaan Righolt & Stuart Callary

9:45	P27	**CT with Implant Movement Analysis in the Work-up of Painful Total Hip Prostheses** *Scott Nodzo (Thomas Listopadzki)*
9:52	P28	**Migration patterns of femoral stems: a systematic review and meta-analysis of RSA studies** *L. van der Water*
9:59	P29	**Stem migration and bone density at 10 years – a randomized radiostereometry and DXA study on a short uncemented hip stem with and without a collar** *Sebastien Daudi*
10:06		**Discussion**
10:15	P30	**Similar femoral stem fixation but less metaphyseal loss of bone mineral density with a taper-wedge design and diaphyseal bone preservation with a long and round-tapered design. A 5-year randomized RSA and DXA study of 50 patients.** *Peter Bo Jorgensen*
10:22	P31	**The Effect of Surgical Approach on Migration of a Novel Short Hip Stem – A Radiostereometric Analysis Study** *Thomas Turgeon*
10:29	P32	**Reverse Total Hip Arthroplasty Fixation Stability at Five Years: A Radiostereometric Analysis (RSA) Study** *Thomas Turgeon*
10:36		**Discussion**

10:45-11:00 Poster session III — Room 1

Moderators: Christiaan Righolt & Stuart Callary

10:45	E12	**Migration in total hip arthroplasty with the Global Tissue Sparing (GTS) stem compared with uncemented HA coated Taperloc stem: a radiostereometric study with 5 years of follow-up** *JH Pasma*
10:47	E13	**Precision of an automated volume-based CT radio-stereometric analysis in a porcine cadaver** *M. Acke*
10:49	E14	**Multi-center RSA study of a novel cementless total knee replacement** *Trevor Gascoyne (Douglas Naudie)*
10:51	E15	**Tibial Baseplate Orientation Which Minimizes Registration Error in Model-Based RSA is Not Aligned with the Anatomical Coordinate System** *Rubiana Monteiro*

11:00-11:30	Coffee break	South Foyer

11:30-12:30 Upper extremity & spine — Room 1

Moderators: Maiken Stilling, Wilhelm Mustad

11:30	P33	**One-year follow-up of 20 patients undergoing the Latarjet procedure: A biomechanical study during an apprehension-relocation test measured with radiostereometry** *Josephine Olsen Kipp*
11:37	P34	**Evaluation of glenohumeral joint kinematics following the Eden-Hybinette procedure with tricortical iliac crest bone graft and the Latarjet procedure. A dynamic radiosteometric cadaver study.** *Josephine Olsen Kipp*
11:44	P35	**Photon-counting detector CT provides high precision quantification using CT-RSA in total wrist implant migration - at a lower radiation dose** *Olof Sandberg (Gustav Lind)*
11:51		**Discussion**
12:00	P36	**Good fixation of Freedom wrist arthroplasty components in a mixed cohort of rheumatoid arthritis and osteoarthritis patients. A radiostereometry study with 2 years follow-up.** *Maiken Stilling*
12:07	P37	**Accuracy and Precision of CT-RSA Migration Measurements of the CapFlex PIP Prosthesis Compared to MBRSA: an Anatomic Specimen Study** *R. Oomen*
12:14	P38	**Quantification of fusion in cervical spine using induced displacement CT-RSA** *Olof Sandberg*
12:21		**Discussion**

12:30-12:40 Announcement of the next meeting — Room 1

12:40-13:45 Lunch — South Foyer

13:45-14:35 Knee 2 — Room 1

Moderators: Elise Laende & Jonathan Jurgens-Lahnstein

13:45	P39	**Denosumab decreases the subsidence of cementless tibial implants by suppression of bone resorption: A randomized, double-blinded RSA study in 54 patients with 5 years follow-up** *Karina Norgaard Linde*
13:52	P40	**Association between bone mineral density and implant migration of cemented and cementless tibial implants: A prospective clinical cohort RSA study in 397 patients** *Karina Norgaard Linde*
13:59	P41	**Antiresorptive treatment reduces the subsidence of tibial implants. A prospective clinical RSA study of 961 patients** *Mohammad Ali Karim*
14:06		**Discussion**
14:15	P42	**Tibial component micromotion of a bicruciate-retaining total knee arthroplasty correlated with early inducible displacement** *Kelly Mills*
14:22	P43	**Construct stability of revision total knee arthroplasty with tibial cones: 2-years of radiostereometric analysis (RSA)** *Petra Heesterbeek*

14:29	P44	**Evaluation of the association between inducible micromotion of unicompartmental knee arthroplasty and patient-reported outcomes. A static and dynamic RSA study.** *Jonathan Hugo Jurgens-Lahnstein*
14:36		**Discussion**

14:45-15:00 Closing ceremony — Room 1

14:45	**Closing remarks** *Trevor Gascoyne*
14:50	**Awards** Best Papers Award – *Presented by Elise Laende* NRT Award – *Presented by Maiken Stilling* Lars Weidenhielm Award – *Presented by Stephan Rohrl* Edward Valstar Award – *Presented by Bart Kaptein*

15:00-15:30 Break — South Foyer

15:30-16:30 iRSA Annual General Meeting — Room 1

Open to all attendees as meeting registration includes iRSA membership

16:30-17:30 iRSA Board Meeting — Room 1

Board members only

17:00-20:30 COA | CORS | CORA Annual Meeting

17:00	**Opening Ceremonies** *East Ballroom B/C*
18:30	**Welcome Reception** *Atrium Foyer*

Validation of early RSA acetabular implant migration thresholds for long-term aseptic loosening with international registry studies

Chan Hee Cho[1], John Abrahams[1,2], Lucian Solomon[1,2], Bart Pijls[3], Liza van Steenbergen[4] and Stuart Callary[1,2]

[1]Centre for Orthopaedics and Trauma and Research, The University of Adelaide, Adelaide, SA
[2]Department of Orthopaedics and Trauma, The Royal Adelaide Hospital, Adelaide, SA
[3]Department of Orthopaedics, Leiden University Medical Centre, Leiden, Netherlands
[4]Dutch Arthroplasty Register (LROI), Netherlands
email: chanhee.cho@adelaide.edu.au

Purpose

Many different acetabular implant designs are used worldwide for total hip arthroplasty (THA), but not all have published evidence of clinical effectiveness. The gold standard for assessing implant performance is 10-year survivorship in registry studies, deeming designs with revision rates below 5% as safe. However, this lengthy observation period delays early detection of unsafe implants. Radiostereometric analysis (RSA) measurements of early cup migration can be used as a surrogate measure to detect poor performing implants earlier than registry studies. Piljs et.a l[1] demonstrated acetabular implants migrating more than 0.2mm at 2 years were at risk of loosening at 10 years, and migration beyond 1mm was associated with an unacceptable risk of long-term revision. However, these migration thresholds were established on only 13 acetabular cup designs from cohort studies susceptible to publication bias and lacked validation against registry databases. Additionally, all 13 cup designs were used clinically prior to 2000 and as new implants are continuously introduced, it is unclear if current thresholds apply to modern prothesis. This study aimed to validate migration thresholds by correlating early RSA cup migration with long-term registry results.

Methods

Our recent systematic review of RSA cup migration studies was used to identify implants with early proximal acetabular cup migration data[2]. The 10-year revision rate of the same cup designs were requested from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) and the Dutch Athroplasty Register (LROI). The mean 12- and 24-month proximal migration was compared with long-term registry revision rates for loosening and previously published thresholds. Acceptable revision rates were classified at <5% revision at 10 years.

Results

There were 29 unique cup designs (84 cohorts) that had published 2-year RSA migration results matched with a 10-year revision rate from the two international registries (16 designs) or the previously published thresholds (13 designs). All newly identified cups with RSA and registry results were below the 5% revision rate threshold at 10-years. There were 16 designs (25 cohorts) that had migrated greater than 0.2mm at 2-years and were considered to be “at risk”

of later loosening. Additionally, 10 designs (27 cohorts) of the newly added cup designs that had acceptable survivorship migrated less than 0.1mm at 1 year and 12 designs (20 cohorts) designs moved greater than 0.1mm were considered to be at risk.

Conclusion

With the inclusion of long-term survivorship data from two international registries, our study was able to establish and validate early acceptable cup migration thresholds. This study was the first to investigate the relationship between proximal migration earlier than two years with long-term registry survivorship and migration at one year is a promising surrogate measure. The recommended acceptable proximal migration thresholds are <0.1mm at 1 year and <0.2mm at 2 years.

References:

1. Pijls, B.G.; Nieuwenhuijse, M.J.; Fiocco, M.; Plevier, J.W.; Middeldorp, S.; Nelissen, R.G.; Valstar, E.R. Early proximal migration of cups is associated with late revision in THA: a systematic review and meta-analysis of 26 RSA studies and 49 survivalstudies. *Acta Orthop* **2012**, *83*, 583-591, doi:10.3109/17453674.2012.745353.
2. Cho, C.H.; Pijls, B.G.; Abrahams, J.M.; Roerink, A.; Katembwe, R.; Baker, A.; Solomon, L.B.; Callary, S.A. Migration patterns of acetabular cups: a systematic review and meta-analysis of RSA studies. *Acta Orthop* **2023**, *94*, 626-634, doi:10.2340/17453674.2023.24580.

Estimating the migration patterns of acetabular implants with the use of early RSA data

Chan Hee Cho [1], John Abrahams[2], Lucian Solomon[2], Elise Laende[4], Bart Pijls[3], and Stuart Callary[1,2]

[1]Centre for Orthopaedics and Trauma and Research, The University of Adelaide, Adelaide, SA

[2]Department of Orthopaedics and Trauma, The Royal Adelaide Hospital, Adelaide, SA

[3]Department of Orthopaedics, Leiden University Medical Centre, Leiden, Netherlands

[4]Systems Design Engineering, University of Waterloo, Ontario, Canada

email: chanhee.cho@adelaide.edu.au

Purpose:

Although long-term RSA studies can provide valuable information of implant migration patterns of implants, there is a paucity of long-term follow-up in the published literature. Within relatively small cohorts, patients are often lost to follow-up, unwell, deceased, or a limited number of matching acetabular bone beads prevents RSA measurements. A recent meta-analysis of RSA studies has identified that the majority of cup migration occurs within the first 6 months[1]. The migration pattern often resembles a Michaelis-Menten curve, where migration of the implant increases and then plateaus after 6 months post-operation. It would be beneficial if the Michaelis-Menten curve could be used as a substitute for missing time points when comparing migration across studies. Additionally, prediction of the maximum migration expected at long term from early data points would further enhance early RSA measurements as a surrogate measure of long-term performance. Therefore, the primary aim of this study was to investigate whether mid-to long-term migration patterns can be estimated with Michalis Menten Curve.

Methods:

The RSA migration measurements of acetabular cups were extracted from previously published systematic review [1]. A Michaelis-Menten curve was used to model RSA migration data of each acetabular design. The extrapolated point of maximum migration of each cup design (EMax) was generated by inputting ≤1-year RSA migration results into the Michaelis-Menten curve. The predicted Emax values were then compared to the matching 5-year RSA migration results of the same design, often reported in follow-up publications.

Results:

The cup migration of 83 cohorts from 47 RSA studies were extracted to produce Michalis Menten Curves. The Michalis Menten Curve was successfully made for 51 cohorts using ≤1

year RSA data. Of these, 10 cohorts (7 different designs) had matching 5-year RSA results to which the predicted Emax could be compared. Seven of the ten cohorts had a predicted EMax that matched (defined as <0.08mm) 5-year in vivo data. Three cohorts (Opticup (n=2) and E1 Biomet (n=1)) had a predicted EMax lower than the actual 5-year RSA results and both of these cup designs are known to have excessive long-term failure rates.

Conclusions:

The use of predictive migration curves to estimate an Emax from early RSA measurements within the first postoperative year demonstrate promising results to identify poor performing implants with continuous long-term migration.

1. Cho, C.H.; Pijls, B.G.; Abrahams, J.M.; Roerink, A.; Katembwe, R.; Baker, A.; Solomon, L.B.; Callary, S.A. Migration patterns of acetabular cups: a systematic review and meta-analysis of RSA studies. *Acta Orthop* **2023**, *94*, 626-634, doi:10.2340/17453674.2023.24580.

Migration in total hip arthroplasty with G7 BiSpherical acetabular system combined with the Global Tissue Sparing (GTS) stem: a radiostereometric study with 5 years of follow-up

Jantsje H. Pasma[1], Bianca Verbeek[1], Ian F. Blom[1,2], Nicole de Esch[1], Nina M.C. Mathijssen[1], Stephan B. W. Vehmeijer[1]

[1]Reinier Haga Orthopedisch Centrum, Zoetermeer, the Netherlands

[2]Department of Radiology, Reinier de Graaf Gasthuis, Delft, the Netherlands

Purpose

Cementless total hip arthroplasty (THA) has shown excellent rates of bone ingrowth, longevity and clinical results. However, due to the growing and aging population, the number of revisions increases, with loosening one of the main reasons of revision. After failure of a primary THA, a more challenging and costly hip revision surgery is needed, mainly due to management of the bone stock loss. Therefore, the new shorter Global Tissue Sparing (GTS) stem (Zimmer Biomet, Warsaw, IN) was developed to prevent the loss of bone stock. In this study, we investigated the migration and evaluated the clinical results of the GTS stem in combination with the G7 BiSpherical acetabular system, a modular system with pre-plugged screw holes (Zimmer Biomet, Warsaw, IN), during 5 years follow-up, to get more insight in the risk on loosening in the long-term.

Methods

In this prospective cohort study, 26 primary THA were performed with the GTS stem combined with the G7 cup. RSA radiographs were obtained in supine position direct postoperatively, at 6 weeks, 6 months, 1, 2 and 5 years postoperatively. Migration of the stem and cup was calculated using model-based radiostereometric analysis (mRSA) in terms of translations and rotations. Double examination was performed at 1 year follow-up to calculate the precision. To evaluate the clinical results, PROMs (NRS pain, HOOS-PS, OHS, HHS, EQ-5D) were registered. Linear mixed models were used to test whether there is a significant migration and change in PROMs over time.

Results

The migration of the stem stabilized between 6 and 6 months. At 5 years postoperatively, we found a statistically significant migration of the stem in all directions, except the rotation about the z-axis. The translation along the x- and y-axes (0.33 (0.27) and -1.43 (1.07) mm, respectively) and the rotation about the y-axis (1.82 (1.89) degrees) were outside the precision interval, indicating real migration.

The cup did not stabilize within 5 years, as a clear migration between 2 and 5 years was found. The cup shows a statistically significant translation along the y- axis and rotation about the x- and y-axes at 5 years follow-up. However, only the translation along the y-axis (0.86 (0.83) mm) lies outside the precision interval. All clinical outcomes improved after 5 years compared to preoperative outcomes.

Conclusion

The GTS stem shows a clear migration in x- and y-direction, which stabilized within 6 months. The G7 cup mainly migrated along the y-axis, but still migrated between 2 and 5 years. Long-term results will give more insight in the migration pattern of the GTS stem in combination with the G7 cup and the relation to revisions.

Migration in total hip arthroplasty with the Maxera Acetabular System compared to the Allofit Acetabular Cup System: a radiostereometric study with 5 years of follow-up

J.H. Pasma[1], C. Icli[1], B. Hesseling[1], I.F. Blom[1,2], R. Bloem[1], N.M.C. Mathijssen[1]

[1]Reinier Haga Orthopedisch Centrum, Zoetermeer, the Netherlands

[2]Department of Radiology, Reinier de Graaf Gasthuis, Delft, the Netherlands

Purpose

Total hip arthroplasty (THA) is a successful treatment in patients with end-stage osteoarthritis of the hip joint. Due to the younger age and a higher activity level of THA patients, there is more need for prosthesis with better survival. The Maxera Acetabular System (Maxera, Zimmer Biomet, Warsaw, IN), a large-head uncemented ceramic-on-ceramic monoblock system, is a new cup specially designed for younger and more active patients, which might have an improved survival, provide a higher range of motion and better stability due to the hemispheric design and featuring larger femoral heads. In this study, we compared the migration and the clinical results of the Maxera Acetabular System to the Allofit Acetabular Cup System, (Allofit, Zimmer Biomet, Warsaw, IN), an uncemented polyethylene cup, during 5 years.

Methods

In this prospective randomized controlled trial, 50 primary THAs were implanted, of which 25 Maxera and 25 Allofit Acetabular Cup Systems, combined with the M/L Taper Hip Prosthesis (Zimmer Biomet, Warsaw, IN). RSA radiographs were obtained in supine position direct postoperatively, at 6 weeks, 3 months, 6 months, 1, 2 and 5 years postoperatively. Migration of the cup was calculated using model-based radiostereometric analysis (mRSA) in terms of translations and rotations. Double examination was performed at 1 year follow-up to calculate the precision. To evaluate the clinical results, PROMs (HHS, OHS, EQ-5D) were registered. Linear mixed models were used to test whether there is a significant difference between the migration of the cups and over time.

Results

The Maxera shows a statistically significant higher total translation compared to the Allofit ($p=0.001$), namely 1.24 (0.99) mm and 0.69 (0.45) mm at 5 years follow-up, respectively. Both cups show an increased translation along the x- and y-axes over time. These translations of the Maxera were higher than the precision interval indicating a real migration, while only the translation along the y-axis of the Allofit is higher than the precision interval. No statistically significant differences were found in the rotation patterns of the cups. Both cups show an increased rotation about the z-axis over time, which also lies outside the precision interval. All PROMs improved after surgery and remained stable during 5 years follow-up. One patient in the Allofit group underwent a revision after 1 year follow-up, because of loosening of the cup.

Conclusion

The Maxera Acetabular System shows a higher total translation compared to the Allofit Acetabular Cup System due to a higher translation along the x-axis at 5 years follow-up. However, no differences were found in clinical outcomes. Long-term results are needed to investigate whether the higher migration is related to a higher revision rate.

Custom triflange acetabular components result in a stable fixation in majority of revision hip arthroplasty cases with large acetabular bone defects. Preliminary short-term RSA results of 15 multicenter cases.

Broekhuis, D.*, Koster,. L.A.*, Heesterbeek, P.J.C.#, M.R. de Bondt#, G.G. van Hellemondt#, R.G.H.H. Nelissen*

* Department of Orthopedics, Leiden University Medical Centre, Leiden, The Netherlands
# Sint Maartenskliniek, Nijmegen, The Netherlands

Purpose

The use of 3D-printed custom implants has evolved rapidly. This technique introduced an alternative reconstructive option for patients with exceptionally large peri-acetabular bone defects (e.g. loosened total hip components). Although these large 3D-printed implants have great potential to improve patient outcomes, analysis on potential complications like loosening is essential. Migration analysis on CTAC is lacking in current literature, therefore the aim of this study was to assess the short-term migration patterns of custom triflange acetabular components (CTAC) used for acetabular reconstruction in patients with large peri-acetabular bone defects. Secondary aims were clinical outcome measures and evaluation of reasons for continuous CTAC migration.

Methods

We performed a prospective multicenter trial including all consecutive patients from one academic and one specialized orthopedic hospital who were treated with a CTAC for the management of Paprosky 3A / 3B acetabular defects. 15 patients with at least 1-year follow-up are included in this preliminary analysis. CTACs (10 in LUMC: AceOS triflange, OSSIS, New Zealand; 5 in SMK: aMace, Materialise, Belgium) were designed based on preoperative pelvic CT-scans using the contralateral side. Model-based RSA migration analysis of the CTAC model was performed using tantalum markers inserted in the iliac crest, ilium and tuber bone. The largest set of stable markers from all bone segments combined formed the rigid body. RSA radiographs were acquired within 1 week postoperatively and at 1.5, 3, 6, and 12 (double examination) months postoperative, and yearly thereafter. Migration of the CTAC, total translation and rotation (TT, TR), cranial-caudal translation and change in inclination angle, is determined with the origin of the migration coordinate system in the center of rotation of the cup. Pain scores (NRS), Quality of life (EQ-5D-3L), HOOS-PS and OHS were obtained. All results are presented as median (IQR).

Results

CTACs migrated at 6 weeks postoperative to median TT and TR (IQR) of 0.29mm (0.22;0.91) and 0.98° (0.43;1.42), respectively. Limited further migration resulted in median TT and TR at 1-year postoperatively of 0.39mm (0.19;1.11) and 0.62° (0.54;1.20). At 1-year follow-up, median (IQR) cranial migration and change in inclination were limited: 0.05mm (-0.00;0.5) and 0.15° (-0.18;0.38). Individual variation in migration patterns between and within patients was present. Double examinations (N=9) demonstrated no systematic bias (mean) and acceptable random errors (SD) in proximal translation and inclination: -0.03mm (0.10) and 0.00° (0.34). Mean (SD) of double examination for TT and TR were 0.25mm (0.20) and 0.63° (0.52). At 1 year follow-up, median NRS

pain, EQ-5D-3L, HOOS and OHS had all improved beyond their respective clinically important difference with respect to preoperative scores. Three implant-related adverse events occurred (2 dislocations, 1 peri-operative fracture). At present, no implants were revised.

Conclusion

Migration analysis with RSA in CTACs showed that the majority of the CTAC cases had a stable fixation at 1 year, after initial migration. At 1 year follow up, patient-reported and clinical outcomes showed substantial improvements compared to the preoperative state. CTAC migration results at 2 year and beyond are needed to evaluate fixation at long-term of this promising CTAC technique.

Quantifying component impingement in total hip arthroplasty: *In vivo* analysis of neck-liner distances during activities of daily living

Shahnaz Taleb,[1,2] Jordan Broberg,[3] James Howard,[4] Brent Lanting,[4] Matthew Teeter[1,2]

1. School of Biomedical Engineering, Western University, London, Ontario, Canada
2. Imaging Research Laboratories, Robarts Research Institute, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada
3. Department of Orthopaedics, University of British Columbia, Vancouver, BC, Canada
4. Division of Orthopaedic Surgery, Department of Surgery, London Health Sciences Centre, ON, Canada

Purpose: Component-on-component impingement following total hip arthroplasty may lead to various unwanted post-operative complications. Because of its consequences, many clinical studies are looking at methods to reduce risk of impingement following hip arthroplasty. However, the assessment of component impingement is largely limited to radiographic qualitative evaluation of the hip joint, finite element analyses, and cadaver studies, which do not accurately reflect the true prevalence of impingement in well-functioning implants. There is therefore a need for more precise measurements of impingement *in vivo* in the research setting. A novel radiostereometric analysis (RSA)-based impingement metric was created and validated to measure impingement risk *in vivo*. The objective of this study is to employ our metric to measure component impingement *in vivo* at various activities of daily living (ADLs) in patients who have undergone total hip arthroplasty (THA).

Methods: Ten participants 6 months – 1-year post-operation who underwent THA through the direct anterior approach were included. All received the same cementless metal-on-polyethylene implant system. RSA examinations were taken of the hip in 9 positions simulating activities of daily living: standing neutral, external rotation, internal rotation, gait (loading response phase), step over, upstairs (weight acceptance phase), downstairs (controlled lowering phase), and frog leg (knees flexed at 30°, hip externally rotated by 45°). Double exposure examinations in the supine position were taken to perform repeatability measurements. A MATLAB-based impingement metric was created to leverage RSA poses to measure distances between implant components; specifically, the femoral neck and the inner circumference of the polyethylene liner. A 1.00 mm impingement threshold was established based on a prior phantom study, with smaller distances (approaching 1.00 mm) being defined as higher risk.

Results: Neck-liner distances were 5.59 – 9.08 mm in standing neutral, 4.23 – 13.09 mm in external rotation, 9.62 – 22.07 mm in internal rotation, 10.31 – 17.23 mm in gait, 9.99 – 19.09 mm in step over, 9.12 – 18.75 mm in upstairs, 5.60 – 18.20 mm in downstairs, 10.03 – 14.13 mm in frog leg, and 10.22 – 20.13 mm in supine positions. External rotation was the position with the smallest neck-liner distance and thus the greatest impingement risk across all participants. Positions of highest risk in our cohort also included downstairs (n = 2) and, interestingly, standing (n = 1). Though, no participants displayed impingement (neck-liner distance <1.00 mm) in any activity. The repeatability of the neck-liner distance in the duplicate supine exams was 0.06 – 0.48 mm. Acetabular cup inclination angles were 32.4° – 41.1° and anteversion angles were 16.3° – 34.6°. Pelvic tilt ranged from 0° – 21°. Sacral slopes ranged from 22° – 43° and 14° – 40° in standing and sitting positions, respectively.

Conclusion: Neck-liner distance as a metric for risk of component impingement at various positions of daily living was measured *in vivo* using our novel impingement metric. As additional participants are recruited, component sizing, acetabular cup position and spinopelvic mobility will be considered to explore potential protective factors against component impingement. This RSA-based metric will be a useful tool in gaining insight on the prevalence of component impingement *in vivo.*

Five-year migration of uncemented femoral components in total knee arthroplasty with either highly cross-linked or conventional polyethylene inserts: a blinded randomized controlled trial using radiostereometric analysis

Ruud de Ridder 1 2 3, Bart L Kaptein 3, Bart G Pijls 3, Rob G H H Nelissen 3, Herman H Kaptijn 1 2

Affiliations

1 Department of Orthopaedics, Lange Land Hospital Zoetermeer, Zoetermeer, Netherlands.

2 Reinier Haga Orthopaedic Centre, Zoetermeer, Netherlands.

3 Department of Orthopaedics, Leiden University Medical Centre, Leiden, Netherlands.

Abstract

Introduction: In the Netherlands, in 2022, loosening of the tibial component was the indication for revision in about 19% of cases compared with 8% for loosening of the femoral component. Instability was the indication for revision in 25% of cases. Compared with tibial components, the migration pattern of uncemented femoral components, as measured by RSA, has only been reported in a few studies. With the increasing number of TKAs which are undertaken in younger patients, and some problems with fixation of the femoral component in the high flexion designs of TKA, further information about the fixation of these components is required.

Aims: The aim of this study was to compare the migration of the femoral component, five years postoperatively, between patients with a highly cross-linked polyethylene (HXLPE) insert and those with a conventional polyethylene (PE) insert in an uncemented Triathlon fixed insert cruciate-retaining total knee arthroplasty (TKA). Secondary aims included clinical outcomes and patient-reported outcome measures (PROMs). We have previously reported the migration and outcome of the tibial components in these patients. Another aim was to add knowledge about the migration of the femoral component and confirm that RSA can be used to predict loosening.

Methods: A double-blinded randomized controlled trial was conducted including 96 TKAs. The migration of the femoral component was measured with radiostereometry (RSA) at three and six months and one, two, and five years postoperatively. PROMs were collected preoperatively and at all periods of follow-up.

Results: In the first two postoperative years, most femoral components translated within 0.5 mm and rotated within 1.0°. Migration was almost completed three months postoperatively. At five years postoperatively, the maximum total point motion (MTPM) migration was 1.14 (95% CI 1.00 to 1.30) and 1.06 (95% CI 0.91 to 1.22) for HXLPE and PE, respectively. There was no clinically relevant difference in terms of migration of the femoral component or PROMs between the HXLPE and PE groups. The mean difference in migration MTPM five years postoperatively, was 0.04 mm (95% CI -0.06 to 0.16) in favour of the PE group.

Conclusion: There was no clinically relevant difference in migration of the femoral component, for up to five years between the two groups. Since RSA studies on the femoral component are scares, these findings will help to establish a benchmark for future studies on migration of femoral components in TKA.

Tibial Component Migration and Metal Ion Release of a Coated and Non-Coated Implant Design

Rebecca A. Hext, James L. Howard, Brent A. Lanting, Edward M. Vasarhelyi, Matthew G. Teeter

Purpose: Metal allergy remains a poorly understood complication following total knee arthroplasty (TKA). It is currently a diagnosis based on exclusion, as patients commonly present with vague pain symptoms. Hard ceramic coatings on implants have been introduced to reduce the release of metal ions and polyethylene materials through wear or corrosion. However, any change to the implant design may impact implant fixation. Radiostereometric analysis (RSA) is the current gold standard research tool that can measure implant movement across exams to assess implant stability. The primary objective of this study is therefore to use RSA to compare tibial component migration between a coated and noncoated implant of the same design. The secondary objective is to compare metal ion release between patients with the coated or noncoated implant.

Methods: Participants (n = 47) have been recruited pre-operatively and were randomized to receive a coated or noncoated implant of the same design. Blood was drawn pre-operatively and at one-year post-operation to measure the concentrations of cobalt, chromium, and nickel. Supine RSA exams were performed at two weeks (baseline), six weeks, three months, six months, and one-year post-operation. Model-based RSA (MBRSA) was used to measure movement of the tibial component between the baseline exam and each follow-up exam as maximum total point motion (MTPM).

Results: At six months post-operation, MTPM was 0.421 ± 0.114 mm for the coated implant (n = 12) and 0.383 ± 0.187 mm for the noncoated implant (n = 8). The difference between groups was nonsignificant (p = 0.743). One participant with the coated implant and one with the noncoated implant had MTPM >0.2 mm between six months and one year post-operation (0.225 mm and 0.283 mm). The increase in blood cobalt concentration from pre-operation to one-year post-operation was 0.004 ± 0.267 µg/L and 0.256 ± 0.167 µg/L for the coated and noncoated implants, respectively (p = 0.111). The increase in blood chromium concentration was 0.353 ± 0.393 µg/L and 0.436 ± 0.449 µg/L for the coated and noncoated implants, respectively (p = 0.697). The increase in blood nickel concentration was -0.014 ± 0.267 µg/L and 0.429 ± 0.873 µg/L for the coated and noncoated implants, respectively (p = 0.224).

Conclusions: Both coated and noncoated groups demonstrated tibial component migration within the acceptable margin at six months post-operation. Furthermore, two patients experienced continuous migration between six months and one year, however all values remained under the threshold for at risk components. There were no significant differences in the concentration of cobalt, chromium, or nickel between the coated or noncoated implant, however the coated implant showed an overall decrease in the amount of nickel post-operation and a smaller change in the concentration of cobalt and chromium from pre-operation to one-year post-operation. These results are promising to support the use of this coated implant, especially in patients with known metal allergies, however longer-term follow-up is still required.

Contact Kinematics and Tibial Component Migration of a Medial-Pivot Total Knee Arthroplasty Design

Rebecca A. Hext, Jordan S. Broberg, James L. Howard, Brent A. Lanting, Edward M. Vasarhelyi, Matthew G. Teeter

Purpose: Total knee arthroplasty (TKA) is a successful procedure to decrease pain and restore function of the knee joint. However, many patients remain dissatisfied, and this may be due to their natural pre-operative knee kinematics not being restored. Natural knee kinematics consist of posterior rollback early and late in flexion and reduced abnormal anterior translation in midflexion. A medial-pivot TKA design mimics these features by distributing forces about the medial condyle. Radiostereometric analysis (RSA) is a dual x-ray imaging technique that can be used to locate the position of components in relation to each other, as well as measure implant movement between longitudinal exams. The goal of this study is therefore to use RSA to assess the anterior-posterior (AP) contact position on the medial and lateral condyles of a medial-pivot design. Abnormal contact kinematics has been found to impact implant fixation. The secondary objective is to determine the relationship between AP position on each condyle and longitudinal migration as measured with RSA.

Methods: Participants (n =22) were recruited to receive a medial-pivot design. Supine RSA exams were taken at 2 weeks, 6 weeks, 3 months, six months, and one-year post-operation. Model-based RSA (MBRSA) was used to measure tibial component migration between the baseline exam and each follow-up exam. At one-year post-operation, standing RSA exams were performed at multiple knee flexion angles (0°, 20°, 40°, 60°, 80°, 100°, and 120° or maximum flexion). The poses of the tibial and femoral component from MBRSA were used to determine the contact locations on the medial and lateral condyle throughout flexion.

Results: For the medial condyle, anterior contact was at -6.00 ± 1.36 mm at 0°, -5.16 ± 1.37 mm at 20°, -4.88 ± 1.33 mm at 40°, -4.62 ± 0.10 mm at 60°, -2.63 ± 1.63 mm at 80°, -3.85 ± 1.48 mm at 100°, and -6.19 ± 2.26 mm at 120°. For the lateral condyle, anterior contact was at -1.50 ± 2.25 mm at 0°, -1.76 ± 2.53 mm at 20°, -2.09 ± 2.48 mm at 40°, -2.18 ± 2.73 mm at 60°, -1.71 ± 2.89 mm at 80°, -4.03 ± 3.82 mm at 100°, and -5.76 ± 4.09 mm at 120°. Mean tibial component migration was 0.26 ± 0.09 mm at 6 weeks, 0.40 ± 0.09 mm at 3 months, 0.42 ± 0.11 mm at 6 months, and 0.45 ± 0.09 mm at 1 year post-operation.

Conclusion: Medial and lateral contact supported a medial-pivot movement as intended by this implant design. One participant appears to have abnormal lateral kinematics, with greater anterior motion in midflexion compared to other participants. Despite these differences, most participants had tibial component migration values within safe threshold ranges (<0.5mm at 6 months post-operation). Those above this value showed implant stabilization between 6 months and 1 year post-operation (<0.2mm). Our results support the kinematics expected with a medial pivot design, however more participants will be required to further assess the relationship between contact kinematics and implant migration.

What is the long-term pattern of migration of the individual implant in cemented and uncemented TKA?

Radosław Wojtowicz, Volker Otten, Sead Crnalic, Kjell G Nilsson
Department of Orthopedics, Umeå University, Umeå, Sweden

Purpose
To analyze the pattern of migration of the individual implant in cemented and uncemented TKA up to ≥20 years.

Methods
Between 1997 and 2003, 97 knees (median age 56 [29-64] years) were operated in an RSA - RCT comparing cemented (C), and 2 types of uncemented TKA fixation; HA coating with additional screws (HA+S) and HA without screws (HA). Follow-up was a mean 21.5 (19-25) years. Marker-based RSA in supine position, bi- planar technique, consistent marker analysis, fictive points for MTPM measurements. Tolerance for ME 0.35, and for CN 100. HOOS and FJS scores for clinical assessment.

Results
At ≥ 20 years, 25 were deceased, 4 revised/reoperated (1 loosening, 1 infection, 2 liner exchange due to wear), and 1 femoral amputation due to chronic infection of a supracondylar femur fracture. 66 TKA:s were still in place, however 18 patients (21 knees) were either living far away or too infirm to attend, leaving 45 (median age 70 [53-88] years) knees available for FU.

Clinical results, median (IQ range): FJS (C) 59 (4-96), (HA+S) 56 (10-98), (HA) 43 (6-75); ns (Kruskal-Wallis)

RSA: Mean (±95%CI) ME (tibia) 0.29 ±0.04, ME (implant) 0.14 ±0.02, CN (tibia) 37 ±6, CN (implant) 24 ±1.5. Precision (±95%CI): MTPM 0.14, X-rotation 0.16, Z-rotation 0.19.

Mean (±95%CI) MTPM at ≥ 20 years: (C) 0.98 ±0.7 mm, (HA+S) 0.57 ±0.2 mm, (HA) 1.91 ±1.3 mm; ns (ANOVA). X-rotation; (C) 0.18° ± 0.49, (HA+S) -0.24° ±0.27, (HA) -0.18° ±1.10; ns (ANOVA). Z-rotation; (C) =.22° ±0.75, (HA+S) -0.08° ±0.24, (HA) -0.55° ±0.92; ns (ANOVA).

A majority of the knees in the 3 groups were stable between 1 year and ≥ 20 years, the change in MTPM between 1 year and ≥ 20 years being a mean (±95%CI) 0.11 (0.35) mm. However, in 8 knees, equally distributed between the groups, the change in MTPM was a mean (±95%CI) 1.12 (1.51) mm, $p<0.001$ (Mann-Whitney U-test). In these knees the MTPM at 1 year was about the size of the mean at 1 year for the respective groups of fixation. Thereafter the MTPM steadily increased during the follow-up. The patients with increasing MTPM expressed a mean 10% lower HOOS and FJS scores compared to the stable implants. Conventional radiographs did not show any differences between stable and unstable knees.

1 cemented knee was revised due to aseptic loosening 15 years postop. MTPM at 1 year was 1.6 mm and increased to 3.1 mm at 10 years. In 1 cemented knee and 1 HA knee the liners were exchanged due to wear at 16 and 11 years postop, respectively. The migration at latest FU before liner exchange for both cases was similar to the mean of respective group.

Conclusion

In the majority of knees there was a stabilization in migration after 1 year irrespective of the magnitude at 1 year. However, several implants (both cemented and uncemented) displayed a continuous increase in migration over time without resulting in clinical symptomatic loosening. Are these implants loose or is the migration pattern a sign of bone remodeling?

(500 words)

Time-zero motion is not related to the bone mineral density in well-fixed uncemented tibial baseplates

Fernando J Quevedo Gonzalez, Matthew Teeter, Eytan Debbi, Yared Tsion, Karlos Zepeda, Himani Kolli, Joseph Lipman, Peter Sculco, Cynthia Kahlenberg, Jonathan Vigdorchik, Timothy Wright, David Mayman

Introduction: Motion of the tibial baseplate after total knee arthroplasty (TKA) can lead to aseptic loosening[1] and alter the ligamentous joint balance carefully obtained through precise component position under robotic assistance. Thus, understanding how implants move from their intraoperative position and which factors contribute to such motion are crucial to identify patients at risk of failure and improve presurgical planning. Therefore, our goal was to quantify the early motion of TKA tibial baseplates from their implanted position before any weight bearing activities to six weeks post-TKA and relate this motion to the bone mineral density (BMD) underneath the implant, a commonly used marker for bone strength.[3]

Methods: This prospective IRB-approved study included 15 primary TKA patients (12 male, ages 54-70) who received the same uncemented tibial baseplate under robotic assistance (Mako, Stryker). All patients received a standard-of-care preoperative CT-scan (120 kVp, 200 mA, 0.625mm spacing, 250 mm field-of-view), which included a BMD reference phantom. A reference postoperative CT-scan was obtained after patients recovered from anesthesia, before any weight bearing or manipulation of the knee. A third CT-scan was obtained six weeks postoperatively. Postoperative CT-scans used a similar protocol to the preoperative scans (140 kVp, 100 mA, 0.625mm spacing, 250 mm field-of-view). The scans were resliced to 0.3mm isotropic voxels before manually segmenting the implants and bones to obtain their 3D surface representation (Mimics, Materialise). The bone and baseplate from the six-week scan were independently aligned to the bone and baseplate from the reference scan (Design-X, 3D Systems). The relative motion of the implant was calculated from the alignment matrices[2] of the implant and bone and expressed at the centroid of the implant. Our precision (i.e., standard deviation of zero displacements in a phantom experiment) was 0.15 mm and 0.2°. The directional translation and rotation of the center of mass and the Maximum Total Point Motion (MTPM) were correlated to the BMD under the baseplate, obtained by aligning the bone from the preoperative scan to the reference scan.

Results: The MTPM of the implant between the immediate postoperative and the six-week postoperative scans ranged from 0.12 to 0.92 mm. On average, the centroid of the baseplates translated 0 mm laterally, 0.04 mm anteriorly and 0.05 mm superiorly. The largest implant rotations occurred around the medial-lateral axis, ranging from 1.6° of anterior tilt to 1.2° of posterior tilt. The average BMD under the implant ranged from 130 mg/cm^3 to 241 mg/cm^3, and was not correlated with any metric of implant motion.

Discussion: To our knowledge, all baseplates in this study remain well-fixed, despite experiencing, in some cases, motion close to the limit of acceptability at six months for uncemented TKA (1.1 mm).[4] The motion of the tibial baseplates was not related to the bone density underneath the implant. However, implant motion could be related to regional variations of BMD (e.g., under medial plateau) and is likely influenced by the patient-specific joint loads. Future studies should include more subjects, and evaluate the contributions of regional BMD and load transfer on implant motion.

References: [1] [2] de Laat et al., J Orthop Res, 2025; [3] [4] Puijk et al., Acta Orthop. 2025

Tibial component migration and inducible displacement for cruciate retaining and posterior stabilized implants in cemented total knee arthroplasty

Elise Laende[1], Michael Dunbar[2], Glen Richardson[2]
[1]Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada
[2]Division of Orthopaedic Surgery, Dalhousie University, Halifax, Nova Scotia, Canada

Purpose

The use of cruciate retaining (CR) or posterior stabilized (PS) implants in total knee arthroplasty (TKA) remains a surgical decision without clear indications in many cases. The increased constraint inherent in PS TKA designs has the potential to transfer loads to the tibial component differently from CR designs. This differing load transfer may have implications for implant fixation which can be evaluated using radiostereometric analysis (RSA) to quantify implant motion within the host bone. The purpose of this analysis was to examine the association between implant type (CR or PS) and longitudinal migration and inducible displacement in a cemented TKA design.

Methods

RSA data for a single cemented TKA implant design (Triathlon, Stryker) were queried from the Halifax RSA Database. Migration results at five scheduled follow-up visits over two years post-operatively were available for 202 TKA operated on between 2010 and 2016 by five surgeons. CR designs included two types of PCL retaining versions: cruciate retaining (CR) and cruciate stabilized (CS). Longitudinal data analysis using marginal models solved with generalized estimating equations was used to determine the association of implant type with overall maximum total point motion (MTPM) migration. The change in migration between one and two years and inducible displacements from weight-bearing single leg stance exams were compared between groups using a Mann-Whitney U test.

Results

CR components were used in 120 cases and PS were used in 82 cases. There were no differences between the groups for age, body mass index (BMI), or proportions of female and male patients. Computer assisted surgery was used in 77% of cases in both groups.

A total of 948 migration exams (mean of 5 exams per patient) over two years of follow-up were included in the longitudinal data analysis. Implant type was statistically significant for longitudinal MTPM migration ($p = 0.02$, adjusted for age, sex, and BMI) with PS implants having higher overall MTPM migration (Figure 1). Mean one-year MTPM migration was 0.45 mm (SD 0.33) in the CR group and 0.58 mm (SD 0.62) in the PS group. The change in migration from one to two years was 0.04 mm (SD 0.15) and 0.07 mm (SD 0.26) in these groups respectively ($p = 0.7$). Mean inducible displacement MTPM was 0.30 mm (SD 0.17) for the CR group and 0.33 mm (SD 0.21) for the PS group and was not different between groups ($p=0.6$).

Conclusion

A large sample of RSA data has allowed us to detect subtle differences in the effect of implant type (CR or PS) on implant migration over two years. While not statistically significant, the differences in migration and inducible displacements between implant type were more pronounced in male patients (n=65) than female patients (n=137), encouraging longer follow-ups and data compilation to investigate these findings further.

Equal tibial and femoral component fixation of a mobile-bearing and fixed-bearing lateral unicompartmental knee arthroplasty with 5-years follow-up

Andreas Bidstrup Hovmark[1,2], Emil Toft Petersen[1,2,3], Jonathan Hugo Jürgens-Lahnstein[1,2,3]
Tobias Dal Vind[1], Søren Rytter[3], Claus Fink Jepsen[3], Maiken Stilling[1,2,3]
[1] AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus, Denmark
[2] Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
[3] Department of Orthopedic Surgery, Aarhus University Hospital, Aarhus, Denmark

Purpose: Differences in stress distribution between mobile-bearing (MB) and fixed-bearing (FB) lateral unicompartmental knee arthroplasty (UKA) designs may affect the fixation of tibial and femoral components. Currently, no studies on migration of the lateral UKA have been made. We compared tibial and femoral component migration of a MB UKA and a FB UKA using radiostereometric analysis (RSA) after 5 years follow-up.

Methods: This prospective consecutive cohort study compared the MB Oxford lateral domed UKA (Zimmer Biomet) and the FB Oxford lateral UKA (Zimmer Biomet) in 14 patients with posterolateral unicompartmental primary knee osteoarthritis. Patients with a mean age of 73 (range 55-88) at 5 years follow-up were included. Patient reported outcome measures in terms of Oxford Knee Scores (OKS) and Knee injury and Osteoarthritis Outcome Score (KOOS) were recorded preoperatively and at 1-, 2-, and 5-years of follow-up. Postoperative follow-up assessments were performed with RSA imaging within 2 days after surgery (baseline) and again at 1-, 2-, and 5-years of follow-up. Clinical outcome measures and complications were recorded until 5 years follow-up. The primary outcome measure was total translation (TT) and total rotation (TR).

Results: The presented data are the preliminary 5-year results of 10 patients. Throughout the follow-up period, tibial and femoral component migration patterns were similar between the MB and FB groups. At 5 years, the mean difference in tibial component TT was 0.4 mm (95% CI: -0.1;0.8), while TR was 0.6° (95% CI: -0.7;1.9). For the femoral components, the mean TT difference was -0.1 mm (95% CI: -0.5;0.2) and the mean TR difference was -0.0° (95% CI: -0.6;0.5). In the MB group, mean tibial component TT and TR were 0.6 mm (95% CI: 0.0;1.1) and 0.6° (95% CI: -0.9;2.2), respectively. For the femoral component, the mean TT and TR were -0.1 mm (95% CI: -0.5;0.3) and 0.2° (95% CI: -0.9;0.5). In the FB group, mean tibial TT and TR were 0.2 mm (95% CI: -0.3;0.7) and 0.0° (95%

CI: -1.5;1.6), respectively. For the femoral component, the mean TT and TR were 0.0 mm (95% CI: -0.4;0.4) and -0.1° (95% CI: -0.8;0.5). Both groups demonstrated similar improvements in clinical outcomes, with significant improvements in OKS and KOOS scores. These improvements were consistent and clinically relevant for all patients at the 5-year follow-up.

Conclusion: The preliminary result of the study concludes that MB and FB lateral UKA designs provide comparable tibial and femoral component fixation over 5 years follow-up. Both the MB and FB lateral UKA designs predict excellent long-term stability, as indicated by similar patterns of TT and TR. Clinical outcomes, including improved functional scores, were equally favorable in both groups. This study provides evidence supporting the efficacy and durability of both MB and FB lateral UKA designs for treating lateral unicompartmental knee osteoarthritis.

The preoperative gait pattern is associated with migration of total knee arthroplasty - an exploratory radiostereometric study with 2 years follow-up

Emil Toft Petersen[1,2,3], Karina Nørgaard Linde[1,2,3], Carl Christian Holkgaard Burvil[1,2], Søren Rytter[1,2,3], Daan Koppens[1,2,3], Jesper Dalsgaard[4], Torben Bæk Hansen[2,4], Maiken Stilling[1,2,3]

[1] *AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus, Denmark*
[2] *Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*
[3] *Department of Orthopedic Surgery, Aarhus University Hospital, Aarhus, Denmark*
[4] *Department of Orthopedics, Gødstrup Regional Hospital, Gødstrup, Denmark*

Purpose: Osteoarthritic changes often cause knee malalignment before total knee arthroplasty, altering bone loading compared to non-osteoarthritic knees. This malalignment is corrected during surgery, balancing the ligaments. Nonetheless, preoperative gait patterns may influence postoperative prosthesis load and bone support, potentially affecting component migration. Thus, the purpose was to investigate the impact of preoperative gait patterns on postoperative femoral and tibial component migration in total knee arthroplasty.

Methods: In a prospective cohort study, 66 patients with primary knee osteoarthritis undergoing cemented Persona total knee arthroplasty were assessed. Preoperative knee kinematics was analyzed through dynamic radiostereometry and motion capture, categorizing patients into four homogeneous gait patterns. The four subgroups were labeled as the flexion group (n = 20), the abduction (valgus) group (n = 17), the anterior drawer group (n = 10), and the tibial external rotation group (n = 19). The femoral and tibial component migration was measured using static radiostereometry taken supine on the postoperative day (baseline) and 3-, 12-, and 24-months post-surgery. Migration was evaluated as maximum total point motion (MTPM).

Results: Of the preoperatively defined four subgroups, the abduction group with a valgus-characterized gait pattern exhibited the highest migration for both the femoral (1.64 mm (CI95% 1.25; 2.03)) and tibial (1.21 mm (CI95% 0.89; 1.53)) components at 24-month follow-up. For the femoral components, the abduction group migrated 0.6 mm (CI95% 0.08; 1.12) more than the external rotation group at 24 months. For the tibial components, the abduction group migrated 0.43 mm (CI95% 0.16; 0.70) more than the external rotation group at 3 months. Furthermore, at 12- and 24-months follow-up the abduction group migrated 0.39 mm (95% CI 0.04; 0.73) and 0.45 mm (0.01; 0.89) more than the flexion group, respectively.

Conclusion: A preoperative valgus-characterized gait pattern seems to increase femoral and tibial component migration until 2 years of follow-up. This suggests that the implant fixation depends on load distributions originating from specific preoperative gait patterns.

Severe knee osteoarthritis increases the risk of continuous migration of cementless tibial implants
A prospective clinical cohort RSA study of 928 patients

Johannes Marsay Dal[1,2], Karina Nørgaard Linde[1,2], Søren Rytter[1,2], Daan Koppens[1], Maiken Stilling[1,2]

[1]Department of Orthopaedics, Aarhus University Hospital, Denmark

[2]Department of Clinical Medicine, Aarhus University, Denmark

Purpose
Aseptic loosening of tibial implants is one of the primary indications for revision surgery. To mitigate this risk, research must further investigate the causes of aseptic loosening. This study aimed to evaluate the effect of preoperative osteoarthritis (OA) grade on tibial implant migration in cemented and cementless knee arthroplasty.

Methods
We conducted a prospective clinical cohort study of 928 patients (928 knees) who underwent medial unicompartmental knee arthroplasty (UKA) or a total knee arthroplasty (TKA) between 2014 and 2018. Cementless tibial implants were used in 635 patients, while 293 received cemented tibial implants. The preoperative OA grade was assessed using the Kellgren-Lawrence (KL) scale for the medial and lateral compartments, and the worst score was used in the analysis. Patients KL scores were KL1 (n=15), KL2 (n=57), KL3 (n=291) and KL4 (n=565). Patients were divided into two OA groups: moderate OA (KL grades 1-3) and severe OA (KL grade 4). Postoperative tibial implant migration was measured with radiostereometric analysis (RSA) at 1, 2, and 5 years, using the baseline RSA recording as reference. Tibial implant migration was evaluated by maximum total point motion (MTPM). The primary outcome was the 1-year MTPM comparison between severe and moderate OA groups, stratified by implant type and fixation method. The secondary outcome was a regression analysis of OA groups as a predictor of continuous migration, defined as MTPM was above 0.2 mm in the time between 1 and 2 years follow-up for both UKAs and TKAs. All analyses were adjusted for age, sex, and BMI.

Results
We found no significant difference in mean MTPM between the OA groups (KL1-3 vs KL4) throughout follow-up. The mean 1-year MTPM difference was 0.00 mm (95% CI -0.24; 0.24) for cementless TKAs, 0.13 mm (95% CI -0.34; 0.09) for cementless UKAs, 0.19 mm (95% CI -0.08; 0.46) for cemented TKAs and 0.03 mm for cemented UKAs (95% CI -0.16; 0.22).

For cementless implants, a significant difference was shown for continuous migration between the OA groups. In the severe OA group (KL4), 23.1% showed continuous migration. Correspondingly, 13.3% of the moderate OA group (KL1-3) showed continuous migration. The severe OA group

demonstrated a mean 77% higher risk of continuous migration than the moderate OA group, adjusted RR= 1.77 (95% CI 1.17; 2.67, P=0.007). A sub-analysis comparing KL3 and KL4 (excluding 40 patients with KL1 or 2 with cementless implants) showed an adjusted risk ratio (RR) of 1.72 (95% CI: 1.11; 2.68, P=0.02).

In contrast for cemented implants, we found no difference in the risk of continuous migration between the OA groups where 26/124 in the moderate OA group had continuous migration compared to 34/131 in the severe group. adjusted RR = 1.22 (95% CI 0.77; 1.93, P=0.401).

Conclusion

We found no difference in implant migration between patients with severe and moderate OA. However, patients with severe OA had a significantly higher risk of continuous migration with cementless tibial implants, but not with cemented implants. The results are preliminary. More detailed results will be explored ahead of the conference.

Title: Comparison of Two CT-based Radiostereometric Analysis Systems

Authors: Maaike R. de Bondt [1], Frank-David Øhrn [2,3], Lars H.W. Engseth [4,5], Anselm Schulz [6], Bart L. Kaptein [7], Stephan M. H. Röhrl [4,5], Petra J. C. Heesterbeek [1]

[1] Research department, Sint Maartenskliniek, Nijmegen, The Netherlands

[2] Orthopaedic Department, Kristiansund Hospital, Møre and Romsdal Hospital Trust, Kristiansund, Norway

[3] Faculty of Medicine and Health Sciences, Department of Neuromedicine and Movement Science (INB), NTNU Norwegian University of Science and Technology, Norway

[4] Division of Orthopaedic Surgery, Oslo University Hospital Ullevål (CIRRO), Oslo, Norway

[5] Faculty of Medicine, University of Oslo, Oslo, Norway

[6] Department of Radiology and Nuclear Medicine, Oslo University Hospital Ullevål, Oslo, Norway

[7] Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

Abstract:

Purpose: To address the limitations of RSA imaging and to eliminate the need for intraoperative marker placement, CT-based radiostereometric analysis (CT-RSA) software systems have been developed. One CT-RSA software system, CTMA (Sectra, Linköping, Sweden), has demonstrated promising precision in multiple studies. The availability of multiple CT-RSA software options can stimulate innovation, expand user choice and improve quality and reliability. A novel CT-RSA software system, V3MA (RSAcore, LUMC, Leiden, the Netherlands), has also been developed (1). Therefore, this study aims to evaluate the precision of V3MA for assessing tibial implant migration compared to CTMA, while also examining the impact of CT scanner type on software performance.

Methods: Data from a porcine knee implant cadaver study were re-used (2). The study assumed zero-motion of the knee implant between the seven scans performed per CT scanner (GE Revolution and Siemens SOMATOM Force. Total: 2 scanners x 7 scans= 14 scans). Pairwise comparisons of exposures were conducted, resulting in 42 examinations analyzed using CTMA and V3MA (21 for each CT scanner). A comparison between scans was performed by aligning two CT scans to compute the translation, rotation and maximum total point motion (MTPM) of the tibial implant. V3MA aligned the scans using the voxel gray values of the bone and implant, whereas CTMA aligned the surface points of the bone and implant. Precision outcomes were reported as the mean with 95% confidence interval (CI) (±1.96*SD) and as separate SDs. The precision of V3MA's MTPM was compared to CTMA's MTPM of peripheral points. Furthermore, the precision of V3MA's and CTMA's MTPM was evaluated across both types of CT scanners.

Results: The MTPM precision by V3MA on the GE scanner data (MTPM: 0.07, CI 0.03 to 0.11, SD: 0.02) and the precision of the MTPM measured by CTMA of the same scanner (MTPM: 0.08, CI 0.03 to 0.12, SD: 0.02) did not vary (difference CI -0.024 to 0.003). MTPM precision measured by V3MA on the Siemens scanner data (MTPM: 0.12, CI 0.00 to 0.24, SD: 0.06) was also comparable to the precision of MTPM measured by CTMA of the same scanner (MTPM: 0.11, CI 0.04 to 0.19, SD: 0.04) (difference CI -0.017 to 0.030). Furthermore, MTPM precision results of both V3MA and CTMA demonstrated superior precision for the GE scanner compared to the Siemens scanner (V3MA: difference CI -0.085 to -0.023; CTMA: difference CI -0.053 to -0.020).

Conclusion: The precision of the new CT-RSA software (V3MA) is comparable to that of CTMA under zero-motion assumptions. However, small inter-scanner differences in CT-RSA precision exist for both software systems.

References

1. de Laat NN, Koster LA, Stoel BC, Nelissen RG, Kaptein BL. Accuracy and precision of Volumetric Matching Micromotion Analysis (V3MA) is similar to RSA for tibial component migration in TKA. J Orthop Res. 2024.
2. Engseth LH, Schulz A, Pripp AH, Rörhl SM, Øhrn F-D. CT-based migration analysis is more precise than radiostereometric analysis for tibial implants: a phantom study on a porcine cadaver. Acta Orthop. 2023;94:207.

CT-based radiostereometric analysis (CT-RSA) Validation: *in vivo* agreement between Volumetric Matching Micromotion Analysis (V3MA) and RSA for a femoral prosthesis in TKA

Jessie E. Robertson[1,2], Bart L. Kaptein[1]

[1]Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

[2]Biomedical Engineering Program, University of Manitoba, Winnipeg, Canada

Purpose:

CT-RSA methods have shown promising results as an alternative to traditional radiostereometric analysis (RSA). The primary benefit of CT-RSA is that it does not rely on implanted marker beads to determine implant migration. Different CT-RSA methods are being developed, including Volumetric Matching Micromotion Analysis (V3MA, RSAcore), a software developed in Leiden that relies on image registration. Preliminary testing has shown that V3MA is a suitable method for determining femoral knee prosthesis migration in a cadaveric dataset. However, further validation of this software is necessary as the previous cadaveric dataset did not contain migration, which is not representative of a clinical scenario. Furthermore, there are no automated quality metrics provided by the software to assess image matching. Quality metrics help to gain confidence in the results of an analysis and quickly identify potential errors. The aim of this study was to compare the agreement between V3MA and RSA in a clinical setting, and determine if V3MA's image matching metric could be used as a quality metric to evaluate image matching.

Methods:

Model-based RSA migration data and V3MA migration data of the femoral knee prosthesis was collected for 22 patients that had undergone total knee arthroplasty (TKA). This dataset was obtained from an RCT comparing two different knee prosthesis designs, and contained CT images taken at year 1 and year 5 following TKA. Models of the bone, prosthesis, and knee were generated from the baseline CT for each patient using Mimics image segmentation software. V3MA uses Elastix software for image registration. Elastix calculates a matching metric to evaluate image mapping, and in an iterative process, transformations are applied to minimize this metric. This Elastix matching metric was analyzed for each patient to determine if it could be used as a quality metric for V3MA. Migration metrics included translations and rotations in 3 planes, and summary metrics including total translation (TT), total rotation (TR) and maximum total point motion (MTPM). Bland-Altman plots were used to compare RSA and V3MA methods.

Results:

The mean difference between V3MA and RSA was -0.06mm for TT, 0.07° for TR, and -0.05mm for MTPM. There was no significant bias in any of these metrics. Furthermore, the limits of agreement were within +/-0.4 mm for TT, within +/-0.8 degrees for TR, and within +/-0.7 mm for MTPM.

The Elastix metric ranged between 0 and 1. The metric value was correlated to the quality of the image matching. When the images were not matched, the metric value approached 0, and when a good match was found, the metric value approached 1.

Conclusion:

V3MA is a suitable CT-RSA method for calculating femoral prosthesis migration within a clinical setting. The mean differences between V3MA and RSA were minimal within a clinical dataset, and show that V3MA can detect clinically relevant changes in migration of <1 mm of translation and <1 degree of rotation. Lastly, an automated output metric was identified that was representative of image matching quality, and can be used for future analysis to assess V3MA image matching.

Title: Dose reduction does not impact precision of CT-RSA in total knee arthroplasty – a clinical trial

Authors: Fredrik Bru[1, 2]; Lars H.W. Engseth [2, 3]; Are Hugo Pripp [4,5]; Anselm Schulz [6]; Tommy Frøseth Aae [1, ,7] ; Stephan M. Röhrl [2, 3] ; Otto Schnell Husby [1, 7]; Frank-David Øhrn [1, 7]

[1] Orthopaedic Department, Kristiansund Hospital, Møre and Romsdal Hospital Trust, Kristiansund, Norway

[2] Division of Orthopaedic Surgery, Oslo University Hospital Ullevål (CIRRO), Oslo, Norway

[3] Faculty of Medicine, University of Oslo, Oslo, Norway

[4] Oslo Centre of Biostatistics and Epidemiology, Research Support Services, Oslo University Hospital, Oslo, Norway.

[5] Faculty of Health Sciences, OsloMet – Oslo Metropolitan University, Oslo, Norway.

[6] Department of Radiology and Nuclear Medicine, Oslo University Hospital Ullevål, Oslo, Norway

[7] Faculty of Medicine and Health Sciences, Department of Neuromedicine and Movement Science (INB), NTNU Norwegian University of Science and Technology, Norway

Abstract:

Purpose: Radiostereometric analysis has been the gold standard for migration analysis of implants for decades, due to its high accuracy and precision. The CT based RSA method (CT-RSA) was developed some years ago, with proven high accuracy and precision in shoulder and hip (1-3). Our research group demonstrated the precision of the method in a porcine cadaver with standard and low doses for knee implants (4). The aim of this study was to see if our conclusion from the previous dose reduction porcine cadaver study also applies in a clinical setting.

Methods: This study is part of the multiple blinded randomized controlled Cless*TKA* trial, comparing the novel 3D printed uncemented medially stabilized total knee arthroplasty (GMK Sphere 3D metal, Medacta International, Switzerland) with a well-documented 3D printed uncemented TKA implant (Triathlon Tritanium CR, Stryker, Mahwah, USA) (5, 6). 50 patients were recruited at Kristiansund Hospital, Norway. Patients were allocated to the study (GMK Sphere, n=25) or the control (Triathlon Tritanium, n=25) group. All surgeries were performed using mechanical alignment between January and June 2023. Double CT acquisitions of all patients were performed with a GE Revolution CT scanner (GE Healthcare, Chicago, USA) within 2 days (standard dose, 80 mAs, 0.06 mSv, n=50) and at 3 months (low dose, 20 mAs, 0.01 mSv, n=50) postoperatively. All images were reconstructed with a Bone Plus MAR algorithm. The CT-RSA analysis of the tibial components was performed using the CTMA software (Sectra, Linköping, Sweden). One of the authors (FDØ) certified by Sectra, performed the analyses. The remaining authors were blinded for the type of implant and the dosage level. The primary endpoint was the difference in precision (mean) of maximum total point motion (MTPM) of the two dose levels. Similar calculations were performed for center of mass (COM) translations and rotations. We created an equivalence interval of 0-0.1 mm. If the difference of MTPM was more than 0.1mm this would represent a clinical meaningful difference. Differences in migration and rotation were calculated using linear mixed model analysis with a p-value < 0.05 considered significant. We also tested the variability of the means (SD comparison test).

Results: The results for the precision data between the standard and low dose analysis showed a mean difference (95% CI) of 0,007mm (-0.018 to 0.032, p=0.574). The SD comparison test showed the translation was at a mean 0.116mm, P=0.190. The mean

difference (95% CI) between the two implant groups was 0.006mm (-0.019 to 0.030, P=0.662). The transversal, varus and internal rotations showed a mean difference (95% CI) of -0.027mm (-0.077 to 0.024, p=0.3) 0.005mm (0.019 to 0.029, p=0.7), and 0.012mm (-0.012 to 0.036, p=0.3) respectively. The COM medial, posterior and proximal mean difference for translations (95% CI) were for -0.001 (CI -0.010 to 0.008, p=0.8), 0.013 (0.001 to 0.024, p=0.03) and 0.002 (-0.017 to 0.021, p=0.8) respectively.

Conclusion: The study confirmed that dose reduction from 0.06 to 0.01mSv, does not impact the precision of CT-RSA in tibial components in a clinical setting.

1. Brodén C, Sandberg O, Olivecrona H, Emery R, Sköldenberg O. Precision of CT-based micromotion analysis is comparable to radiostereometry for early migration measurements in cemented acetabular cups. Acta orthopaedica. 2021;92(4):419-23.
2. Brodén C, Giles JW, Popat R, Fetherston S, Olivecrona H, Sandberg O, et al. Accuracy and precision of a CT method for assessing migration in shoulder arthroplasty: an experimental study. Acta Radiol. 2020;61(6):776-82.
3. Brodén C, Sandberg O, Sköldenberg O, Stigbrand H, Hänni M, Giles JW, et al. Low-dose CT-based implant motion analysis is a precise tool for early migration measurements of hip cups: a clinical study of 24 patients. Acta Orthop. 2020;91(3):260-5.
4. Øhrn FD, Engseth LHW, Pripp AH, Röhrl SMH, Schulz A. Dose reduction does not impact the precision of CT-based RSA in tibial implants: a diagnostic accuracy study on precision in a porcine cadaver. Acta Orthop. 2023;94:550-44.
5. Hasan S, van Hamersveld KT, Marang-van de Mheen PJ, Kaptein BL, Nelissen R, Toksvig-Larsen S. Migration of a novel 3D-printed cementless versus a cemented total knee arthroplasty: two-year results of a randomized controlled trial using radiostereometric analysis. Bone Joint J. 2020;102-b(8):1016-24.
6. van der Lelij TJN, Marang-van de Mheen PJ, Kaptein BL, Toksvig-Larsen S, Nelissen R. Continued Stabilization of a Cementless 3D-Printed Total Knee Arthroplasty: Five-Year Results of a Randomized Controlled Trial Using Radiostereometric Analysis. The Journal of bone and joint surgery American volume. 2023.

Evaluation of migration analysis with AI-based CT-RSA and preoperative 3D-planning in total hip arthroplasty

Albin Christensson[1], Hassan M. Nemati[2], Kristina Ydström[3] and Gunnar Flivik[1].
[1]Department of Orthopedics, Skåne University Hospital, Clinical Sciences, Lund University, Lund, Sweden.
[2]Ortoma AB, Gothenburg, Sweden.
[3]Radiation Physics, Department of Hematology, Oncology and Radiation Physics, Skåne University Hospital, Lund, Sweden.

Abstract:
Purpose: Computed tomography (CT) has become a valuable tool for preoperative planning and intraoperative navigation in total hip arthroplasty (THA). CT can also quantify postoperative implant migration without the need for implanted bone markers, making it a promising alternative to the current gold standard Radiostereometry (RSA) (1-3), namely CT-RSA. In addition, with the use of artificial intelligence (AI), images can be processed automatically with high accuracy reducing time requirement (4). We have previously showed that AI-based CT-RSA is a promising alternative to model-based RSA, even though prosthetic CAD models were not implemented in the CT-RSA software (5).
In this study, our goal was to evaluate, on both cup and stem, an AI-based software using 3D CT-images for preoperative planning and postoperative implant migration (CT-RSA) compared to conventional RSA, both with implemented prosthetic CAD models.

Methods: 26 patients with primary uncemented THA were preoperatively 3D-planned and perioperatively navigated. They were followed and analyzed with AI-based CT-RSA within 2 days postoperatively and at 3, 12 and 24 months. 10 of the patients had implanted tantalum markers at surgery and were also followed with RSA and the results were compared to CT-RSA. Prosthetic CAD-models were used for both RSA and AI-based CT-RSA analysis. Double CT- and RSA-scans were taken to evaluate precision. The preoperative plan was compared to actual perioperatively chosen implants. A patient reported outcome measures questionnaire; The Forgotten Joint Score (FJS) (6) was collected preoperatively, at 3 months, 1 and 2 years postoperatively.

Results: AI-based CT-RSA showed consistent migration patterns, with most migration in the first 3 months, then levelled out. After 2 years, the CT-RSA results showed that the stem had subsided 0.11 mm and the cup had migrated cranially 0.31 mm (y-translation). In addition, the stem retroverted 0.54° (y-rotation) and the cup inclination decreased 0.50° (z-rotation). Bland-Altman plots indicated good agreement between RSA and AI-based CT-RSA. Overall, we found high correspondence between RSA and AI-based CT-RSA in translations but more divergent rotation results. AI-based CT-RSA precision was consistently slightly better than RSA. For AI-based CT-RSA, the translational precision ranged from 0.06 – 0.16 mm, whereas RSA precision ranged from 0.17 - 0.38 mm. For rotation, the precision ranged between 0.08 - 0.51° for AI-based CT-RSA and 0.24 - 0.66° for RSA, respectively. The agreement between planned and actual size of cup was 25 out of 26, and 23 out of 26 stems. Patients reported a statistically significant clinical improvement after surgery (FJS: $p<0.001$). The mean preoperative FJS score was 8, and 3 months after surgery it was 62. At 24 months the FJS score was 90.

Conclusion: CT-based 3D-planning gives predictable results and using the system for migration analysis with AI-based CT-RSA seems to be as a feasible alternative to RSA with

good agreement between the measurement methods and stable results including better CT-RSA precision. In addition, implementing AI makes it user-independent, faster and more accessible.

1. Kaptein BL, Pijls B, Koster L, Kärrholm J, Hull M, Niesen A, et al. Guideline for RSA and CT-RSA implant migration measurements: an update of standardizations and recommendations. Acta Orthop 2024; 95: 256-267. 10.2340/17453674.2024.40709.

2. Sandberg OH, Kärrholm J, Olivecrona H, Röhrl SM, Sköldenberg OG, Brodén C. Computed tomography-based radiostereometric analysis in orthopedic research: practical guidelines. Acta Orthop 2023; 94: 373-378. 10.2340/17453674.2023.15337.

3. Brodén C, Sandberg O, Olivecrona H, Emery R, Sköldenberg O. Precision of CT-based micromotion analysis is comparable to radiostereometry for early migration measurements in cemented acetabular cups. Acta Orthop 2021; 10.1080/17453674.2021.1906082: 1-5. 10.1080/17453674.2021.1906082.

4. Zhou S, Zhou F, Sun Y, Chen X, Diao Y, Zhao Y, et al. The application of artificial intelligence in spine surgery. Front Surg 2022; 9: 885599. 10.3389/fsurg.2022.885599.

5. Christensson A, Nemati HM, Flivik G. Comparison between model-based RSA and an AI-based CT-RSA: an accuracy study of 30 patients. Acta Orthop 2024; 95: 39-46. 10.2340/17453674.2024.35749.

6. Behrend H, Giesinger K, Giesinger JM, Kuster MS. The "forgotten joint" as the ultimate goal in joint arthroplasty: validation of a new patient-reported outcome measure. J Arthroplasty 2012; 27: 430-436.e431. 10.1016/j.arth.2011.06.035.

A single CT is enough for CT-based radiostereometric analysis

Emil Toft Petersen[1,2,3], Andreas Bidstrup Hovmark[1,2], Maiken Stilling[1,2,3]

[1] *AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus, Denmark*
[2] *Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*
[3] *Department of Orthopedic Surgery, Aarhus University Hospital, Aarhus, Denmark*

Purpose: Radiostereometric analysis (RSA) is considered the gold standard method for measuring implant migration. Recently, there has been a high interest in computed tomography-based RSA (CT-RSA). However, this method induces a significant radiation dose to the patient, especially with multiple follow-ups. This study presents a method where only a single CT is required for CT-RSA. We hypothesize that single CT-RSA is comparable to the gold standard RSA.

Methods: This study assessed patients from a randomized controlled trial that included 66 patients who underwent cemented total knee arthroplasty. Static radiostereometric images were taken supine on the first postoperative day (baseline) and again at 3-, 12-, and 24 months of follow-up. Implant migrations were determined using three different 2D-3D image registration methods: 1) manual selection of canny-edge detected contours utilizing computed aided design (CAD) models and bone beads (*MBRSA*) as the gold standard, 2) automated silhouette projection method utilizing CAD models and bone beads (*AutoRSA-Surface*), and 3) automated digitally reconstructed radiographs of both implant and bone models obtained from computed tomography (*sCT-RSA*). For all methods, femur and tibia implant migrations were determined and represented in comparable implant coordinate systems. The effect parameters included all six degrees of freedom (Tx, Ty, Tz, Rx, Ry, Rz), total translation (TT) and rotation (TR), and maximum total point motion (MTPM). Interpretations were conducted utilizing mixed model analysis for migration patterns and ANOVA for double examinations.

Results: The presented are preliminary results of 10 patients. Of these, three femur and one tibia analysis were excluded. There were no significant differences between methods for migration patterns. The overall (all follow-up included) mean comparison in MTPM values for the *AutoRSA-Surface* method was -0.10 (95%CI -0.26;0.06) relative to *MBRSA*, while the *sCT-RSA* method was 0.05 (95%CI -0.11;0.21) relative to the *MBRSA*. Double examinations were possible for four patients and revealed overall the best precision for *sCT-RSA*, however, with no statistically significant difference between methods. The precision for the MTPM was 0.05 mm (95%CI -0.81;0.91) for the *MBRSA*, -0.02 mm (95%CI -0.90;0.86) for the *AutoRSA-Surface* method, and -0.04 mm (95%CI -0.75;0.67) for the *sCT-RSA* method.

Conclusion: These preliminary results suggest no compromises in results using *sCT-RSA* or *AutoRSA-Surface* over *MBRSA* for migration analysis of tibial and femoral knee arthroplasty components. In addition, overall bias and random error for double examinations were lowest for *sCT-RSA* compared with the other more traditional methods, which may indicate that *sCT-RSA* with a single computed tomography is the most precise of these three methods. Furthermore, *sCT-RSA* eliminates the need for bone beads while only exposing the patients to a single computed tomography, which keeps radiation exposure to a minimum.

VoluMetric Matching Micromotion Analysis (V3MA) enables accurate quantification of implant inducible displacement between repeat CT examinations

Bart Kaptein[1], Stuart Callary[2,3], Robyn Clothier[2,3], John Abrahams[2,3], Bogdan Solomon[2,3]

1) Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands
2) Centre for Orthopaedic and Trauma Research, The University of Adelaide, Adelaide, South Australia
3) Department of Orthopaedics and Trauma, Royal Adelaide Hospital, Adelaide, South Australia

Purpose

When patients are in pain and infection has been ruled out, plain radiographs are often inconclusive to diagnose loose implants. Inducible Displacement (ID) measurements using radiostereometric analysis (RSA) can be used, but have historically been limited by only being possible for a very limited amount of patients that were included in RSA trials of their primary implant. The recent introduction of Computer Tomography Radiostereometric Analysis (CT-RSA), in which bone markers are not necessary, enables ID analysis of patients using standard clinical CT equipment.

The aim of this study was to investigate if CT-RSA measurements could detect inducible displacements of possibly loose implants prior to revision surgery.

Methods

A small case series of ten patients had infection ruled out and were referred to the Royal Adelaide Hospital (Adelaide, Australia). Nine patients had revision knee prosthesis in situ and one had a primary knee prosthesis. Routine clinical imaging was unable to determine if pain was caused by the implant loosening or soft tissue impingement. Each patient had two CT examinations (standard supine and supine under loading) on the same day prior to planned revision surgery.

3D models of the bone and prosthesis were created from the unloaded CT-data using Mimics (Materialise, Belgium). Unloaded and loaded CT-images including the 3D-models were imported in Volumetric Matching MicroMotion Analysis (V3MA) software (RSA*core*, The Netherlands). V3MA uses open source image registration software called Elastix to match the bone and implant, as indicated by the 3D-models, between unloaded and loaded CTs. Inducible displacement was defined as the relative displacement of the prosthesis with respect to the bone and was used to identify loose femoral or tibial implants. Implant loosening was correlated with intra-operative findings.

Results

Supine external and internal rotation was found to be the easiest method to induce knee implant movement. Three patients are still waiting for revision surgery. The patient with a primary prosthesis did not require revision surgery after CT findings found no clear signs of implant loosening, but did find lateral joint laxity that was treated non-operatively. For the remaining six patients, inducible displacement was consistent with intra-operative findings. One patient had excessive movement within the femoral mega-prosthesis that was confirmed at revision to be implant breakage.

Conclusion

Inducible implant displacement measured with CT-RSA has exciting new potential to be used as diagnostic outcome measure beyond the traditional research setting. We recommend the application of load to be performed under clinician guidance in the direction likely to induce movement expected. Further research and development of the V3MA software is required to allow easier use for non-experienced observers to perform the measurements and most importantly correctly interpretation of findings.

Wear in total hip arthroplasty with the Regenerex cup: a radiostereometric study with 10 years of follow-up

J.H. Pasma[1], I.F. Blom[1,2], N. de Esch[1], S.B.W. Vehmeijer[1], N.M.C. Mathijssen[1]

[1]Reinier Haga Orthopedisch Centrum, Zoetermeer, the Netherlands

[2]Department of Radiology, Reinier de Graaf Gasthuis, Delft, the Netherlands

Purpose

Uncemented acetabular cups in total hip arthroplasty (THA) have shown excellent rates of bone ingrowth, longevity and clinical results. However, liner wear is a common problem in THA, which could result in osteolysis and loosening, respectively, especially in younger and more active patients. Liner wear is caused by the free radicals generated during the formation of highly cross-linked polyethylene. Infusing vitamin-E into HXLPE increases its oxidative stability and reduces wear without altering material properties. In this study, we evaluated the wear and the clinical results of the Regenerex Ringloc+ cup (Zimmer Biomet, Warsaw, USA), a porous-titanium coated cup with a E-Poly™ HXLPE liner, which consists of cross-linked polyethylene infused with vitamin E, over a period of 10 years.

Methods

This study is part of a multicenter randomized controlled trial comparing the uncemented Global Tissue Sparing (GTS) stem and uncemented Taperloc stem (Zimmer Biomet, Warsaw, USA) with a head diameter of 32 mm, both combined with an uncemented Regenerex Ringloc+ cup and a E-Poly™ HXLPE liner. Twenty-five patients were included. Wear was calculated using model-based radiostereometric analysis (mRSA). RSA radiographs were obtained in supine position direct postoperatively, at 3 and 6 months, 1, 2, 5 and 10 years postoperatively. Wear was expressed in mm in medial, proximal and anterior direction with respect to the postoperative position. The wear rate in proximal direction was expressed in mm/year. Clinical outcomes were measured using the Harris Hip Score (HHS), the Hip disability and Osteoarthritis Outcome Score (HOOS) questionnaire and the EQ-5D.

Results

Over the 10-year period, the medial wear was -0.026 (± 0.086) mm, proximal wear was 0.077 (± 0.213) mm, and anterior wear was 0.070 (± 0.275) mm. The wear rate in the proximal direction between 1 and 5 years was 0.001 (± 0.052) mm/year and between 5 and 10 years 0.006 (± 0.042) mm/year. No acetabular components had to be revised. All clinical outcomes improved after 10 years compared to preoperative results.

Conclusion

The results show a low wear after a period of 10 years. The wear rate between 5 and 10 years is higher compared to the wear rate between 1 and 5 years. However, the proximal wear rate is still lower than the proposed wear threshold of 0.1 mm/year (Dumbleton et al. (2002)), which indicates an excellent cup survival. Longer follow-up is needed to relate the wear to future cup revisions because of wear-related problems.

The effect of implant, surgical and patient factors on the long-term wear of highly cross-linked polyethylene liners

Stuart Callary[1,2]; Deepti Sharma[1,2]; Taisha D'Apollonio[1], Ryan Quarrington[1], David Campbell[1,3], Lucian Solomon[1,2]

[1]Centre for Orthopaedic and Trauma Research, The University of Adelaide, Adelaide, South Australia
[2]Department of Orthopaedics and Trauma, Royal Adelaide Hospital, Adelaide, South Australia
[3]Wakefield Orthopaedics, Calvary Adelaide Hospital Adelaide, South Australia

Purpose
Radiostereometric analysis (RSA) is the most accurate radiographic method to measure the three-dimensional *in vivo* wear of highly cross-linked polyethylene (XLPE) acetabular components. Less sensitive measurement methods from plain radiographs often report higher than expected wear rates and the variation within results inhibits correct clinical interpretation. The wear rate of older polyethylene implants was affected by factors including manufacturing method, articulation size of the bearing and age of patient. Optimally, RSA wear studies of XLPE would enable investigation of these factors but are often limited to a small patient cohort monitoring one implant design. The aim of this study was to investigate the influence of implant and patient factors on the long-term wear rate of XLPE as measured using RSA. Implant factors investigated in this study included 1) manufacturing method, 2) articulation size and 3) cup size; surgical factors included 4) cup inclination and 5) version; patient factors included 6) age, 7) BMI and 8) activity.

Methods
153 patients prospectively enrolled in in six specific cohorts underwent long-term RSA examination to measure XLPE wear at 7, 10 and 14 years follow-up. Three different XLPE liners were used with irradiation doses of 5Mrad (Cohort A), 10 Mrad (Cohorts B, C, D) and 9Mrad (Cohorts E, F). The early wear rates of each cohort were previously published at two or five years. The proximal femoral head penetration (FHP) was calculated between the day 2 RSA exam and latest follow-up. The proximal wear rate was calculated as the slope of the FHP between one year and latest follow-up excluding liner bedding-in.

Results
Combined analysis of six cohorts revealed the proximal wear rate of a XLPE liner manufactured at the lowest irradiation dose (5Mrad) was significantly higher than two XLPE liners irradiated with 9- and 10-Mrad ($p < 0.001$). For patients with a 5Mrad XLPE liner, a one degree increase in inclination angle increased the proximal wear rate by 0.003mm/year. No other implant factor investigated affected the long-term wear rate. Importantly our study confirmed the non-inferiority of XLPE wear rates against larger articulations (36/40mm) when compared to standard articulations (28/32mm); and younger patients (40-64years) were not associated with increased wear rates compared to older patients (65-74years).

Conclusion
The low long-term wear rates below 0.02mm/year are encouraging for the continued excellent survivorship of XLPE implants in their second decade of use. Knowledge of the different wear rates for each implant design gives manufacturers additional insight into appropriate radiation doses for new liner development. This body of work supports the use of accurate RSA measurements in the stepwise introduction of new implant designs. We recommend that liners with early proximal wear rates greater than 0.03mm/year warrant further longer-term investigation.

The influence of surgical approach on acetabular cup migration and wear in total hip arthroplasty – a multi-centre radiostereometric analysis study

Vasarhelyi E[1,2], Bohm ER[3,4,5], Gascoyne T[5], Howard J[1,2], Lanting B[1,2], Teeter M[1,2], Turgeon TR[3,4,5].

[1]London Health Sciences Centre, London, Ontario, Canada
[2]Lawson Health Research Institute, London, Ontario, Canada
[3]Concordia Joint Replacement Group, Winnipeg, Manitoba, Canada
[4]Department of Surgery, University of Manitoba, Winnipeg, Manitoba, Canada
[5]Orthopaedic Innovation Centre, Winnipeg, Manitoba, Canada

Purpose:

Aseptic loosening and implant wear are two common causes of failure in modern total hip arthroplasty (THA) devices. This study sought to elucidate differences in acetabular cup migration and linear wear on a single implant system between three common surgical approaches to the hip.

Method:

Eighty six patients requiring primary total hip arthroplasty for osteoarthritis were enrolled at two Canadian centres into two separate studies. All patients received a Pinnacle Gription acetabular cup and ALTRX polyethylene component (DePuy Synthes). In the primary study, patients received a standard THA via one of three surgical approaches; posterolateral, direct lateral, direct anterior. In the secondary study, patients received a dual-mobility THA (DM-THA) via any surgical approach. Adjuvant acetabular screw fixation was not used in either study. Participating surgeons performed their preferred surgical approach. Due to cancellation of funding, the enrollment goals of 90 patients in the primary study (30 per approach) and 30 patients in the secondary study, were not fully achieved. To bolster overall patient numbers, the two studies were combined for continuation of follow-up out to the study endpoint. Patients underwent supine RSA imaging at 6 weeks (baseline), 3, 6, 12, and 24 months following surgery. The primary study outcome was acetabular cup subsidence (superior migration) at 24 months. Secondary study outcomes were total translation of the acetabular cup (vector migration) and wear (linear head penetration).

Results:

Study group assignment was as follows: Posterior – 45 patients (36 THA + 9 DM-THA), Lateral – 18 patients (17 THA + 1 DM-THA), Anterior – 23 patients (22 THA + 1 DM-THA). At the time of writing, 75% of patient data was available and are presented in the results below.

Across all patients, mean subsidence of the acetabular cup was 0.06mm (SD: 0.26), 0.04mm (SD: 0.25), and 0.03mm (SD: 0.37) at 6, 12, and 24 months respectively, indicating stable fixation. Mean total translation of the acetabular cup was 0.44mm (SD: 0.38), 0.43mm (SD: 0.32), and 0.52mm (SD: 0.42) at the same time points. Mean wear reached 0.29mm (SD: 0.16) at 24 months with an annual rate of 0.05 mm/yr (SD: 0.20) derived from linear regression of each patient's linear head penetration into the cup.

The rate and pattern of acetabular cup subsidence was very similar between surgical approach groups. The posterior approach group trended towards less total translation compared to the lateral ($p=0.30$) and anterior ($p=0.15$) groups but this may be an influence of disproportional sample sizes. The anterior approach group demonstrated higher cumulative wear at 24 months compared to the posterior group ($p<0.01$), but disproportionate sample size may explain this discrepancy as the annual wear rate did not differ significantly ($p=0.71$).

Conclusion:

This study sought to compare acetabular cup migration patterns between different surgical approaches to the hip. With the available data, we were not able to conclude whether surgical approach significantly influences acetabular cup migration or wear within the first two post-operative years, but early evidence suggests there is little difference. Clinical follow-up is on-going and these findings will be re-evaluated with a fulsome dataset and a sub-analysis of the DM-THA cohort.

Total hip arthroplasty for acute acetabular fractures through the replace-in-situ philosophy: radiographic assessment of cup stability

John M. Abrahams[1,2], Boopalan Ramasamy[1,2], Xiang Dong[3], Daud Chou[4], Kerry Costi, L. Bogdan Solomon[1,2], Stuart A. Callary[1,2,]

[1] Centre for Orthopaedic and Trauma Research, Adelaide University, Adelaide, South Australia
[2] Department of Orthopaedics and Trauma, Royal Adelaide Hospital, Adelaide, South Australia
[3] Department of Orthopedic Surgery, The Second Hospital of Anhui Medical University, Hefei City, Anhui Province, China
[4] Orthopaedic Trauma Unit, Nuffield Health Cambridge Hospital, Cambridge, United Kingdom

Purpose
The challenge of treating acute acetabular fractures with THA is achieving stability of the acetabular component, particularly in cases with column disruption, severe wall comminution and compromised bone quality. The radiographic assessment of acetabular component stability following acute acetabular fracture differs from the assessment of THA for other pathologies as some pelvic landmarks including the teardrop may not be visualised and fracture healing may alter the reference landmark over time. The aim of this study was to determine the early stability of acetabular components of total hip arthroplasty (THA) treating acute acetabular fractures through a replace-in-situ technique using standard radiographic assessment techniques as well as radiostereometric analysis (RSA), the gold standard for assessment of implant stability.

Methods
We prospectively investigated 29 patients who underwent THA to manage an acute acetabular fracture in which patients underwent post-operative in clinic radiographic assessment of acetabular component stability and detailed measurements using both RSA and manual techniques. The latter were performed based on pelvic reference landmarks located below and above the fracture. Greater than 3mm of proximal translation and/or 5º of rotation around the sagittal axis were considered diagnostic of a loose acetabular component.

Results
The median proximal translation and sagittal rotation of the cohort measure by RSA was 0.5mm (range -1.3 to 22.0) and 0.0° (-3.0 to 5.0) respectively. There was a significant disparity between different measurement techniques. Clinic review, RSA and manual measurements using reference landmarks below and above the fracture diagnosed 2, 6, 14 and 19 components to be loose respectively.

Conclusion
Visual assessment of radiographs in clinic underestimate and manual radiographic measurements overestimate acetabular component loosening in these complex cases. Accurate measurements of acetabular component migration are recommended in these cases as pelvic landmark identification on consecutive plain radiographs are influenced by both pelvic projection on plain radiographs and fracture fragment migration during healing.

Enhancing torsional stability with interlocking plates in undisplaced femoral neck fractures – a randomized controlled trial using radiostereometric analysis

Magnus Høgevold[4], Michaela Manalili Hansen[5,6], Jan-Egil Brattgjerd[1,3], Stephan Röhrl[1,2]

1 Division of Orthopaedic Surgery, Oslo University Hospital

2 Institute of Clinical Medicine, Faculty of Medicine, University of Oslo, Oslo

3 Faculty of Health Sciences, Oslo Metropolitan University

4 Division of Orthopaedic Surgery, Diakonhjemmet Hospital, Oslo, Norway

5 Department of Orthopaedic Surgery and Traumatology, Odense University Hospital, Odense, Denmark

6 Institute of Clinical Medicine, University of Southern Denmark, Odense, Denmark

Purpose: Traditionally, undisplaced intracapsular femoral neck fractures have been treated with internal fixation using conventional screws or pins, but with variable functional outcomes and reoperation rates due to fixation failure[1, 2]. To improve fixation stability and promote bone healing, interlocking plates have been developed. In vitro studies suggest that these locking plates enhance fixation primarily by increasing torsional stability[3, 4]. However, the extent to which femoral neck interlocking plates improve fixation stability during surgery remains unclear. According to this, we tested whether a novel interlocking plate improves stability during the internal fixation of undisplaced femoral neck fractures in vivo.

Methods: We evaluated postoperative fracture motion using radiostereometric analysis (RSA) in 25 patients undergoing internal fixation of undisplaced femoral neck fractures (Garden stages 1-2). The patients were randomized to receive either conventional fixation with two Hansson pins (n=12) or fixation with the Hansson Pinloc system (n=13), allowing three titanium pins interlocked in an aluminum plate. The implantation of tantalum markers followed a predefined protocol, with 8-10 markers placed in both main segments peroperatively. RSA was performed after weight-bearing and at 4, 12, 26, and 52 weeks. Motion, both by translation and torsion, was calculated using the first post-weight-bearing image as the baseline. Additionally, clinical scores (Harris Hip Score, Timed Up and Go test, EQ-5D, and Pain -Visual Analog Scale) were assessed at the same time intervals.

Results: Seventeen patients completed the one-year follow-up. Three patients died, two in the Pinloc group and one in the Pin group. Three patients underwent reoperation with arthroplasty due to avascular necrosis—one in the Pinloc group and two in the Pin group. Two additional patients in the Pinloc group required re-osteosynthesis after experiencing a subtrochanteric fracture. Migration was assessed in 8-12 patients using RSA at different time points throughout the follow-up period.

Median total torsional stability was significantly higher in the Pinloc group at 4 weeks postoperatively: 2.49° (range 0.94°–4.76°) compared to 7.51° (range 6.80°–20.93°) in the Pin group ($p = 0.036$). After one year, the median torsional stability was 3.85° (range 0.81°–5.80°) in the Pinloc group, versus 7.44° (range 0.84°–28.32°) in the Pin group ($p = 0.154$).

No differences were observed in total translation. At 4 weeks, median translation was 4.53 mm (range 0.50 mm–8.99 mm) in the Pinloc group, compared to 5.81 mm (range 2.79 mm–11.12 mm) in the Pin group. After one year, the corresponding measurements were 3.92 mm (range 0.46 mm–8.99 mm) in the Pinloc group and 4.24 mm (range 0.67 mm–13.05 mm) in the Pin group. There were no significant differences in clinical outcomes.

Conclusion: Our results indicate that locking plates increase torsional stability in patients treated with interlocked pins during fracture healing. This biomechanical finding is in accordance with material strength theory and preclinical trials[3, 4]. Larger clinical studies are needed to determine whether the improved torsional stability leads to better functional outcomes or comes at the expense of increased risks such as avascular necrosis or subtrochanteric fractures.

[1] Lewis SR, Macey R, Eardley WG, Dixon JR, Cook J, Griffin XL. Internal fixation implants for intracapsular hip fractures in older adults. Cochrane Database Syst Rev. 2021;3:CD013409.
[2] Gjertsen JE, Fevang JM, Matre K, Vinje T, Engesaeter LB. Clinical outcome after undisplaced femoral neck fractures. Acta Orthop. 2011;82:268-74.
[3] Brattgjerd JE, Loferer M, Niratisairak S, Steen H, Stromsoe K. Increased torsional stability by a novel femoral neck locking plate. The role of plate design and pin configuration in a synthetic bone block model. Clin Biomech (Bristol). 2018;55:28-35.
[4] Brattgjerd JE, Steen H, Stromsoe K. Increased stability by a novel femoral neck interlocking plate compared to conventional fixation methods. A biomechanical study in synthetic bone. Clin Biomech (Bristol). 2020;76:104995.

Title: CT with Implant Movement Analysis in the Work-up of Painful Total Hip Prostheses

Authors: Thomas Listopadzki, MD; [a] K. Keely Boyle, MD; [a] Scott R. Nodzo, MD [a]

[a] Department of Orthopaedics, Jacobs School of Medicine and Biomedical Science, University at Buffalo, The State University of New York at Buffalo

Purpose: CT-Implant movement analysis (CT-IMA) is an emerging technology that utilizes two overlaid stressed CT scans of the hip to evaluate loosening and micromotion of femoral and acetabular components. We evaluated the ability of this technology to identify the stability of hip implants in a consecutive series of patients with painful total hip replacements (THRs).

Methods: Eighty patients were evaluated for painful total hip prostheses between May 2021-October 2023 from two high volume arthroplasty surgeons. Clinical and demographic data were collected. Plain radiographs and CT-IMA scans of the affected hip were evaluated. Overt radiographic loosening was considered 1-2mm circumferential radiolucent lines within the modified Gruen or Delee & Charnley zones or change in implant position between serial radiographs. CT-IMA scans demonstrating implant motion > 0.5mm were generally considered loose. Patients were categorized by implant stability based on plain radiographs and CT-IMA scans and grouped into three categories: XR Stable-IMA Stable, XR Loose-IMA Stable, and XR Loose-IMA Loose. Hip dysfunction and Osteoarthritis Outcome Score for Joint Replacement (HOOS, JR) scores were calculated for each group from initial to final follow-up. Statistical analysis was performed with two-tailed paired *t*-tests.

Results: Mean follow up was 14.0±10.0 months. 35/80 patients had symptoms of thigh pain, 23/80 presented with startup pain, and 54/80 presented with groin pain. Sixty-six patients fell

into the XR Stable-IMA Stable group (Group 1), 6 into the XR Loose-IMA Stable group (Group 2), and 8 into the XR Loose-IMA Loose group (Group 3). Within Group 1, mean HOOS, JR scores improved from 49.5±18.4 to 64.2± 18.9 (*P*=.004). Fourteen patients underwent revision surgery with all found to have stable components. Within Group 2, mean HOOS, JR scores improved from 57.7±19.7 to 69.1±21.5 *(P*=.01). Two patients underwent revision surgery and had well-fixed components. Within Group 3, HOOS Jr scores improved from 45.5±18.1 to 71.8±15.4 *(P*=.04). Seven patients underwent revision surgery and were found to have loose components. One patient was lost to follow up.

Conclusion: CT-IMA was able to identify both loose and stable total hip implants independent of radiolucent lines around total hip components. Two of the patients in the XR Loose-IMA Stable group had surgery and were found to have well fixed components. The remaining four patients had collared stems with radiolucent lines but stable IMA scans with the patients stable clinically. All patients had radiolucent lines in at least one of the evaluated zones which often gave concern for loosening. This technology has promise as an adjunct in the work up of painful total hip prostheses in helping to determine clinically stable implants and by the identification of spot welding in both the femoral and acetabular components, which may be more meaningful than traditionally used peri-implant radiolucencies.

Migration patterns of femoral stems: a systematic review and meta-analysis of RSA studies

The Edward Valstar Award

L. van der Water[1]; C.H. Righolt[2,3,4]; T. Gascoyne[2]; B.L. Kaptein[1]; R.G.H.H. Nelissen[1]; B.G.C.W. Pijls[1]

Affiliations:

[1] Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

[2] Orthopaedic Innovation Centre, 320-1155 Concordia Avenue, Winnipeg, MB, R2K 2M9, Canada

[3] Department of Surgery, University of Manitoba, AE101-820 Sherbrook Street, Winnipeg, MB, R3A 1R9, Canada

[4] Biomedical Engineering Program, University of Manitoba, E2-390 EITC, 75 Chancellor's Circle, Winnipeg, MB, R3T 5V6, Canada

Purpose

We conducted a systematic review and meta-analysis of radiostereometric analysis (RSA) studies of primary total hip replacements (THR) to investigate the early and long-term migration patterns of femoral stems and the influence of implant characteristics on stem migration.

Methods

A systematic search of PubMed, Web of Science, Cochrane, and Embase databases to identify all RSA studies on femoral stem migration following primary THR. Studies that reported on migration at two or more postoperative time points within two years after THR were included. Studies with fewer than five THRs or with more than 5% hip fractures at baseline were excluded. Subsidence and retroversion at 6 weeks, 3 and 6 months, 1, and 2 years were included for analysis when reported. Extracted implant characteristics included implant design, stem fixation and coating (if uncemented).

Results

118 studies were included in this meta-analysis, reporting the subsidence of 200 cohorts of 88 different femoral stems, including a total of 5,210 patients. The cemented stems had a mean pooled subsidence of 0.28 mm (95% confidence interval [CI] 0.19-0.38) at 3 months, 0.26 mm (CI 0.17-0.35) at 6 months and 0.38 mm (CI 0.28-0.48) at 2 years. The subsidence of the cemented stems increased by 0.15 mm (CI 0.11-0.19) between 6 months and 2 years. The uncemented stems had a mean pooled subsidence of 0.30 mm (CI 0.20-0.40) at 3 months, 0.19 mm (CI 0.10-0.27) at 6 months and 0.29 mm (CI 0.19-0.39) at 2 years. The

subsidence of the uncemented stems did not increase significantly between 3 months and 2 years (0.01 mm; CI -0.02-0.03).

Of the cemented stems, the stem type that subsided most was the taper-slip. The taper-slip had a pooled mean subsidence of 1.05 mm (CI 0.84-1.25) at 2 years, whereas the composite beam (0.18 mm; CI 0.11-0.25) and the resurfacing hips (0.03 mm; CI -0.15-0.22) had a significantly lower mean subsidence at 2 years.

Of the uncemented stems, porous-coated stems had the highest mean subsidence of 0.40 mm (CI 0.19-0.62) at 2 years. Uncoated cementless hip stems had a mean subsidence of 0.37 mm at 2 years (CI 0.03-0.70). The hydroxyapatite (HA) coated stems showed the least mean subsidence at 2 years (0.25 mm; CI 0.12-0.37).

The mean pooled 2-year retroversion was 0.62 degrees (CI 0.48-0.75) for cemented stems and 0.67 degrees (CI 0.46-0.88) for uncemented stems.

Conclusion

Our meta-analysis demonstrated that the majority of stem subsidence occurs within the first 6 months. Overall, the cemented stems subsided more than the uncemented stems, but the higher subsidence of cemented stems is mostly caused by the taper-slip stems, which subsided 5.8 times as much as the composite beams. Additionally, cemented stems continued to subside beyond 6 months and showed no clear stabilization within 2 years, whereas uncemented stems demonstrated stabilization after 3 months. Within the uncemented stems, HA-coated stems migrated the least and porous coated stems migrated the most. Stem retroversion, however, did not stabilize, with most stems continuing to rotate over time. The cemented and uncemented stems showed similar retroversion patterns.

Stem migration and bone density at 10 years – a randomized radiostereometry and DXA study on a short uncemented hip stem with and without a collar

BY SÉBASTIEN DAUDI, VASILEIOS ZAMPELIS, OLA BELFRAGE, GUNNAR FLIVIK

DEPARTMENT OF ORTHOPAEDICS, SKÅNE UNIVERSITY HOSPITAL, LUND, SWEDEN
DEPARTMENT OF CLINICAL SCIENCES, MEDICAL FACULTY, LUND UNIVERSITY, LUND, SWEDEN

Purpose

Short, uncemented hip stems might provide a favourable alternative in total hip arthroplasty (THA) by preserving proximal bone stock by reduced stress shielding. We evaluated and compared the migration and periprosthetic bone remodelling of a short stem with and without a collar, using radiostereometric analysis (RSA) to measure implant migration and dual energy x-ray absorptiometry (DXA) to evaluate periprosthetic bone remodelling. In this study we present 10-year follow-up results, completing previously published 2-year and 5-year RSA and DXA studies. To our knowledge, this is the first study to present long-term data for a short, uncemented stem using both RSA and DXA.

Methods

Methods: 50 patients (34 men) with osteoarthritis and mean age of 60 years, scheduled for unilateral THA were recruited and enrolled in the randomised clinical trial between 2012 and 2013. Patients were randomised to either a collared or a collarless version of the short, uncemented Furlong Evolution® stem (JRI Orthopaedics Ltd., Sheffield, UK) introduced in 2011. Implant migration was the primary outcome and reference RSA examinations were conducted on the first postoperative day and then repeated at 2 weeks, 3 months, 1, 2, 5, and 10 years. Baseline DXA examinations were made within 2 weeks of surgery with subsequent assessments at 1, 2, 5 and 10 years. Patient-reported outcome measures (PROMs), HOOS, EQ-5D and FJS were collected.

Results

45 patients remained at the 10-year follow-up. RSA showed early implant stabilisation and osseointegration within 3 months after initial subsidence of 0.62 mm (95% CI: 0.33 – 0.91) and 0.76 mm (95% CI: 0.55 – 0.96) for collared and collarless stems respectively. Retroversion was seen up to 3 months with mean rotation along the Y-axis of 0.82° (95% CI: 0.57 – 1.07) and 0.99° (95% CI: 0.49 – 1.48) for collared and collarless stems respectively. Minimal further migration was observed up to 10 years. Subgroup analysis of the collared stems adjusting for contact in the collar to calcar interface did not show a significant increase in stability in cases where the collar was resting on the calcar (16 out of 25 stems). Net bone mineral density (BMD) at 10 years was -3.3% (95% CI: -9.2 – 2.7) and -2% (95% CI: -7.3 – 3.4) in collared and collarless stems respectively. The presence of a collar did not result in any statistically significant differences neither for RSA nor DXA results. PROMs improved as expected and remained high up to 10 years in both groups. None of the stems were revised.

Conclusion

The short stem remains stable at 10 years and preserves periprosthetic bonestock, both with and without a collar with excellent reported PROMs. RSA indicates early osseointegration within the first 3 months after surgery with minimal subsidence or rotation observed past this point, indicating that short stems with metaphyseal fixation can achieve satisfactory stability within a short time frame comparable to that of conventional stems. These findings support the use of short stems in younger and more active patients.

Contact

Sébastien Daudi, MD
Department of Orthopaedics, Skåne University Hospital
Department of Clinical Sciences, Medical Faculty, Lund University, Lund, Sweden
221 85, Lund, Sweden
sebastien.daudi@med.lu.se

Similar femoral stem fixation but less metaphyseal loss of bone mineral density with a taper-wedge design and diaphyseal bone preservation with a long and round-tapered design. A 5-year randomized RSA and DXA study of 50 patients.

Peter Bo Jørgensen [1,2] pbjr@clin.au.dk

Morten Homilius [1]

Daan Koppens [2]

Torben B. Hansen [1,3]

Maiken Stilling [2,3]

1. Department of Orthopaedics, University Clinic for Hand, Hip and Knee Surgery, Gødstrup Hospital.

2. Department of Orthopaedics, Aarhus University Hospital.

3. Department of Clinical Medicine, Aarhus University.

Abstract

Purpose

The Tri-Lock bone preserving stem is a new collarless proximal-coated tapered-wedge design providing metaphyseal contact for rotational and axial stability to increase biological fixation and preserve bone. The Summit stem is a classic well-proven collarless proximal-coated long and round-tapered design intended aimed to eliminate hoop stress and provide initial stability during biological metaphyseal fixation.

Methods

In a patient-blinded RCT, 52 patients at mean age 60 (CI 58—62) received Tri-Lock (n=26) or Summit (n=26) femoral stems with a Pinnacle cup, a cross-linked polyethylene liner, and a CoCr head. Patients were followed for 5 years with RSA, DXA, and PROMs.

Results

At 2-year follow-up, the mean difference in subsidence was 0.14 mm (95% confidence interval [CI] -0.27 – 0.56). At 5-year follow-up, for the Tri-Lock and Summit stems, the mean subsidence was -0.38 (CI -0.72 – -0.04) and -0.24 (CI -0.57 – 0.09), and the mean retroversion was 1.68° (CI 0.80 – 2.55), and 1.53° (CI 0.68 – 2.37), respectively.

There was initial periprosthetic bone resorption for both stems. At 5-year follow-up, the mean metaphyseal bone loss was minimal for the Tri-Lock stem (zone 1: -2.8% vs. -11.5%) while the Summit stem preserved the medial diaphyseal bone better (zone 6: -7.1% vs. -13.6%). At the medial stem tip, BMD was increased with the Summit stem (zone 5: +3.4% vs. -1.5%).

Conclusion

The Tri-Lock and the Summit stems displayed similar migration until mid-term follow-up. At 3 months both stems had lost metaphyseal peri-prosthetic bone mineral density (BMD). During the following years, the taper-wedge stem design regained metaphyseal BMD the best. Contrarily, the long and round-tapered stem design regained or even increased diaphyseal BMD. The long-term effect of this difference is unknown.

The Effect of Surgical Approach on Migration of a Novel Short Hip Stem – A Radiostereometric Analysis Study

Turgeon TR [1,2,5], Lanting, B [3], Vasarhelyi EM [3], Howard J [3], Teeter MG [3,4], Gascoyne [5], Leighton J [6], Bohm [1,2,5]

1. Concordia Joint Replacement Group
2. University of Manitoba
3. London Health Sciences Centre
4. Lawson Health Research Institute
5. Orthopaedic Innovation Centre
6. Dalhousie University

Purpose: Surgical approach in total hip arthroplasty is currently not known to affect stability of the hip stem. This study aimed to compare hip stem migration patterns between three common surgical approaches to the hip for a single implant system using model-based RSA over the first 2 post-operative years.

Method: Sixty patients requiring primary total hip arthroplasty for end-stage osteoarthritis were enrolled at three Canadian centres. All patients received an ACTIS hip stem and Pinnacle acetabular cup with a metal or ceramic femoral head and a polyethylene liner (DePuy Synthes). Patients were divided into study groups based on the surgical approach predominant to each enrolling surgeon until at least 20 patients were obtained per group; postero-lateral [Posterior], direct lateral [Lateral], and direct anterior [Anterior]. Patients underwent supine RSA imaging at 6 weeks (baseline), 6, 12, and 24 months following surgery as well as a weight-bearing image at 24 months. The primary study outcome was femoral stem subsidence at 24 months and change in subsidence between 12-24 months. Secondary study outcomes included total translation (vector sum) and maximum total point motion (MTPM). Patient reported outcome measures were captured throughout the study. Statistical analysis utilized paired and unpaired t-tests with significance set at $p \leq 0.05$.

Results:

At the time of writing, 60% of patient data at 24-months was available and are presented in the results below.

Mean femoral stem subsidence across all groups was -0.01mm (SD: 0.12), -0.01mm (SD: 0.16), and 0.04mm (SD: 0.14) at six, 12, and 24 months. Change in femoral stem subsidence between 12 and 24 months was negligible at 0.05mm, indicating stable primary fixation. Mean MTPM of the femoral stem across all groups was 0.82mm (SD: 0.63), 1.04mm (SD: 1.08), and 0.95mm (SD: 0.71) at the same time points, further indicating stable fixation at 24 months.

Between surgical approach groups, there was no clear difference in mean femoral stem subsidence at any time point with exception of Anterior at 24 months ($p=0.04$). The Posterior group trended towards less total translation than both Lateral and Anterior groups at six, 12, and 24-month follow-ups, but statistical significance was not reached ($p>0.14$). The Posterior group showed lower MTPM at all follow-ups, reaching statistical significance at 24 months ($p=0.03$ versus Anterior | $p=0.01$ versus Lateral).

However, these statistical differences may be influenced by the limited data thus far collected at the 24-month follow-up. Additionally, there was no obvious trend of femoral stem retroversion in any of the three surgical approach groups, nor any statistical significance between them ($p>0.27$).

Conclusion:

This study sought to compare femoral stem migration patterns between different surgical approaches to the hip. With the available data, we were not able to conclude whether surgical approach influences femoral stem fixation within the first two post-operative years, but early evidence suggests there may be slight differences. Clinical follow-up is on-going and these findings will be re-evaluated with a fulsome dataset.

Reverse Total Hip Arthroplasty Fixation Stability at Five Years: A Radiostereometric Analysis (RSA) Study

Thomas Turgeon, Colin Burnell, and David Hedden

Concordia Joint Replacement Group, Winnipeg, Canada
University of Manitoba, Winnipeg, Canada

Introduction

A novel reverse total hip arthroplasty (RTHA) design has been developed with enhanced mechanical stability at extremes of motion in all planes by reversing the articulating surfaces using a femoral cup and acetabular ball. The purpose of this study was to assess the implant-bone fixation using radiostereometric analysis, assess the linear wear of the cross-linked polyethylene insert and monitor the clinical safety and efficacy of this novel design as a hip arthroplasty device.

Methods

Twenty two subjects with end-stage osteoarthritis of the hip were enrolled at a single center in this regulator-approved investigational device trial. All patients underwent a RTHA utilizing at least 1 acetabular screw for augmented fixation with the Reverse Hip Replacement System (Reverse HRS, Hip Innovation Technology). RSA markers were inserted into the innominate bone and proximal femur prior to implant insertion. Model-Based RSA was used to assess migration between the implants and bone and the polyethylene linear wear with assessments at six weeks (baseline), six, 12, 24 and 60 months from surgery. Patient reported outcome metrics were collected pre-operatively and at each post-operative visit including Oxford Hip Score-12, Harris Hip Score (HHS), European Quailty of Life (EQ-5D), HOOS and SF-36. Analysis was performed using one-sided and paired t-tests.

Results

The cohort consisted of 11 females and 11 males with mean age of 70.8 years and body mass index 31.3 kg/m^2. Mean femoral subsidence from baseline at 6, 12, 24 and 60 months was 0.01±0.12mm, -0.00±0.19mm, -0.00±0.19mm and -0.06±0.21mm, all below the published critical threshold of 1.5mm ($p< 0.0001$), respectively. Mean acetabular subsidence from baseline was 0.06±0.10mm, 0.08±0.11mm, 0.06±0.14mm and 0.09±0.15mm at the same time points, all below the published critical threshold of 1mm ($p<0.0001$). Polyethylene linear wear was measured at 0.11±0.05mm, 0.11±0.05mm, 0.10±0.05mm and 0.19±0.16mm at the same time points, respectively. The assessed wear was just above detection limits for RSA at 60 months. There was a significant improvement in function and pain with THA and as collected by PROMS (HOOS, Oxford-12, HHS, SF-36, EQ-5D). One subject required two-stage revision for infection.

Conclusion

The femoral and acetabular components both appeared well fixed at 5 years as assessed with RSA suggesting a low-risk of long-term aseptic loosening. Polyethylene linear wear was approaching the detection limit for assessment and within accepted limits. The results indicate acceptable radiographic safety and clinical efficacy of this novel reverse total hip arthroplasty design.

One-year follow-up of 20 patients undergoing the Latarjet procedure: A biomechanical study during an apprehension-relocation test measured with radiostereometry

Josephine Olsen Kipp[1,2], Emil Toft Petersen[1,2,3], Maiken Stilling[1,2,3], Sepp de Raedt[1], Anna Zejden[4], Rikke Jellesen Åberg[4], Thomas Falstie-Jensen[3], Theis Muncholm Thillemann[3]

[1] AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus N, Denmark
[2] Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
[3] Department of Orthopaedic Surgery, Aarhus University Hospital, Aarhus N, Denmark
[4] Department of Radiology Aarhus University Hospital, Aarhus N, Denmark

Background: The Latarjet procedure is the first-choice treatment for patients with recurrent anterior shoulder instability with glenoid bone loss. However, the stabilizing effect of the Latarjet procedure in these patients is sparsely described.
The aim was to evaluate the glenohumeral joint (GHJ) kinematics during an apprehension-relocation test in patients with anterior shoulder instability before and after their Latarjet procedure and in comparison with their contralateral healthy shoulder.

Methods: Twenty patients scheduled for the Latarjet procedure were enrolled. The patients were examined preoperatively with bilateral radiostereometric analysis (RSA) and one year after surgery on the operated shoulder with an apprehension-relocation test. Bone models were obtained from computed tomography (CT) scans and aligned with the RSA images. Anatomical coordinate systems were applied to evaluate the GHJ kinematics with two methods: 1) the humeral head center location relative to the glenoid center and 2) the GHJ contact point relative to the glenoid center. As a secondary outcome, bone block resorption was evaluated one year after surgery by CT.

Results: No difference in GHJ kinematics was found between the healthy and the postoperative GHJ. Compared with the preoperative injured shoulder, the postoperative mean humeral head center was 0.8 mm (95%CI 0.1; 1.4) more superior and 0.7 mm (95%CI -0.1; 1.4) more posterior during the apprehension test and 0.5 mm (95%CI 0.0; 1.1) more posterior during the relocation test. The postoperative contact point was posterior to the coracoid bone block and 0.9 mm (95%CI -0.2; 2.0) more posterior than in the preoperative injured shoulder during the apprehension test. The articulating area of the coracoid bone block was decreased by 63.9% (95%CI 75.5; 114.6) one year after surgery.

Conclusions: The Latarjet procedure restored the humeral head center location posterior and superior and the contact point posterior to the coracoid bone block. This indicates that the GHJ stabilizing effect of the Latarjet procedure results from the conjoined tendon rather than directly from the coracoid bone block, which is supported by the large bone block resorption one year after surgery.

Evaluation of glenohumeral joint kinematics following the Eden-Hybinette procedure with tricortical iliac crest bone graft and the Latarjet procedure. A dynamic radiosteometric cadaver study.

Josephine Olsen Kipp[1,2], Emil Toft Petersen[1,2,3], Theis Muncholm Thillemann[2,3], Sepp de Raedt[1], Thomas Falstie-Jensen[3], Lærke Espelund Borgen[1], Annemarie Brüel[4], Emil Toft Petersen[1,2,3], Maiken Stilling[1,2,3]

[1] AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus, Denmark
[2] Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
[3] Department of Orthopedic Surgery, Aarhus University Hospital, Aarhus N, Denmark
[4] Department of Biomedicine, Aarhus University, Aarhus, Denmark

Background: Patients with anterior shoulder instability typically experience symptoms during active abduction and external rotation of the shoulder. In cases of glenoid bone loss, bone grafting procedures such as the Eden-Hybinette procedure with tricortical iliac crest bone graft and the Latarjet procedure can be performed to stabilize the glenohumeral joint (GHJ).

Aim: To evaluate the GHJ kinematics throughout an external shoulder rotation following the Eden-Hybinette and Latarjet procedure in comparison with 15% glenoid bone loss and the native GHJ.

Methods: Eight human specimens were examined with dynamic radiostereometry (dRSA) during an automated 85 ° external rotation of the GHJ at a 30- and 60-degree GHJ abduction. The test was performed with anteriorly directed loads of 0, 10, 20, and 30 N in four stages: 1) the native joint, 2) 15% anterior glenoid bone loss, 3) the Eden-Hybinette procedure, and 4) the Latarjet procedure. Specimen-specific bone models from computed tomography scans were aligned with dRSA images using digitally reconstructed radiographs. Anatomical coordinate systems were applied to describe the GHJ kinematics measured as the humeral head center and the contact point.

Results: A 15% glenoid bone loss resulted in up to 9.5 mm (95%CI 1.0; 18.0) more anterior and up to 8.1 (95%CI 0.8; 15.4) more inferior humeral head translation. The Latarjet and Eden-Hybinette procedures resulted in up to 9.7 mm (95%CI 0.5; 18.8) more posterior and a 7.4 mm (95%CI 0.3; 14.4) more superior humeral head center location compared to 15% glenoid bone loss. With 0-20 N anterior directed loads, the Latarjet procedure resulted in a more posterior humeral head center and contact point of up to 7.6 mm (95%CI 3.6; 11.5), especially in 60 degrees of GHJ abduction, compared to the Eden-Hybinette procedure. Opposite, at 30 N anterior-directed load, the Eden-Hybinette procedure resulted in a more posterior humeral head center of up to 7.6 mm (95%CI 0.3; 14.9) in 30 degrees GHJ abduction compared to the Latarjet procedure.

Conclusion: Following the infliction of anterior shoulder instability with 15% glenoid bone loss on human specimens, the Eden-Hybinette and Latarjet procedures restored the GHJ kinematics towards the native GHJ kinematics during a loaded external shoulder rotation. These results support considering the Latarjet procedure in patients who need the stabilizing effect with the arm in the abducted and externally rotated position (e.g., throwers) and the Eden-Hybinette procedure in patients exposed to high anterior-directed loads with the arm at lower abduction angles (e.g. epilepsia).

Photon-counting detector CT provides high precision quantification using CT-RSA in total wrist implant migration - at a lower radiation dose

Gustav Lind (1), Olof Sandberg (2*), Erik Tesselaar(1), and Simon Farnebo(1)
(1) Linköping University, Sweden (2) Sectra, Sweden *presenting author

Purpose:
Total wrist arthroplasty (TWA) has been proven effective to treat painful wrist arthritis. Still, the primary concern after TWA remains implant loosening, with an implant survival rate of 82% for the Motec arthroplasty system at ten years. We have in this study assessed if there are benefits with using novel photon-counting detector CT (PCD-CT) compared to conventional energy-integrating detector CT (EID-CT) for improved CT-RSA precision, and if the radiation dose can be reduced without losing precision.

Methods:
Eight patients with TWA implants (Motec, Swemac AB, Linköping, Sweden) were scanned with PCD-CT both post-surgery, at 6 months, and at 12 months. Additionally, one cadaveric wrist with the same implant was scanned 20 x 2 times with EID-CT, and 20 x 2 times with PCD-CT at two radiation doses. There was manual repositioning of the cadaver in between each scan. PCD-CT scans were reconstructed with 0.2 mm and 1.0 mm slice thickness. Migration and precision data were calculated using CTMA (Sectra, Sweden). Precision is calculated as SD multiplied by 1.96 and comparisons were made using ANOVA and Šídák's multiple comparison tests.

Results:
For the patients as measured by median (LQ, UQ); at 6 months the base of the proximal component had moved -0.04 (-0.08, 0.05) mm distally. At 12 months it had moved 0.01 (-0.09, 0.06). The total translation at these two time points was 0.10 (0.06, 0.16) mm and 0.10 (0.07, 0.22) mm respectively. The rotation around the proximal/distal axis at these two time points was 0.03 (-0.21, 0.25) degrees and 0.06 (-0.11, 0.45) degrees. The total rotation was 0.29 (0.14, 0.35) degrees and 0.25 (0.13, 0.48) degrees.
For the distal component the base had moved 0.04 (0.02, 0.06) mm and 0.02 (-0.02, 0.04) mm at 6 and 12 months. The corresponding total translation was 0.09 (0.07, 0.21) mm and 0.15 (0.07, 0.23) mm. The rotation around the proximal/distal axis was 0.44 (0.10, 0.71) degrees and 0.17 (-0.07, 0.49) degrees at 6 and 12 months. The total rotation was 0.45 (0.31, 0.82) degrees and 0.35 (0.27, 0.53) degrees.
For rotation measurements, the precision (95% CI) ranged from 0.04 to 0.32 degrees with EID-CT and from 0.02 to 0.10 degrees with PCD-CT. For migration measurements, the precision ranged

from 0.02 to 0.03 mm with EID-CT and from 0.02 to 0.07 mm with PCD-CT.
For the cadaveric wrist, the precision of total implant rotation was significantly better with PCD-CT at half the radiation dose (0.08 degrees) compared to full-dose EID-CT (0.15 degrees, $p = 0.002$). Similarly, precision of translation at the implant tip was reduced with half-dose PCD-CT (0.02 mm) relative to EID-CT (0.03 mm, $p = 0.04$).

Conclusions:
This study illustrates that PCD-CT can enable migration data measurements at a very high precision at a lower radiation dose. The precision values all compare favourably to literature, and the results indicate that the Motec arthroplasty components only show very small movements during the first year after implantation.

Good fixation of Freedom wrist arthroplasty components in a mixed cohort of rheumatoid arthritis and osteoarthritis patients. A radiostereometry study with 2 years follow-up.

Maiken Stilling[1,2,3] and Janni Kjærgaard Thillemann[1,2,3,4]

Affiliations

[1] AutoRSA Research Group, Aarhus University Hospital, Aarhus, Denmark
[2] Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
[3] Department of Orthopedics, Aarhus University Hospital, Aarhus, Denmark
[4] Department of Orthopedics, Gødstrup Hospital, Herning, Denmark

Purpose

Wrist arthroplasty is a motion-preserving treatment option for low-demand patients with painful degenerative wrist disease. Generally, the reported complication rate is high, which leave some reservations about the treatment, with these costly implants. Three arthroplasty types have been utilized in Europe, but only one recent study has investigated the fixation of the cementless ReMotion and Motec wrist arthroplasty using radiostereometric (RSA) imaging with 2 years follow-up[1]. This study aimed to evaluate the fixation of the Freedom wrist arthroplasty until 2 years follow-up.

Methods

A consecutive cohort of 26 patients (3 men) at mean age 61 years (range 30; 81) with either rheumatoid arthritis or osteoarthritis of the wrist received the cementless Freedom wrist arthroplasty between 2018 and 2022. Three surgeons operated all patients. RSA was performed post-operative, at 3 months, 1 and 2 years postoperative. Migration of the carpal and radius component was measured with model-based RSA and reported as total translation and total rotation (TR). Patient-reported outcomes (pain and QuickDASH score (0–100, 0 best)), functional outcomes (grip strength and pain on NRS), radiological changes, and complications were evaluated preoperatively and until 2 years follow-up. Means with 95% confidence interval (CI) were reported.

Results

For the radius component, there was no statistically significant TT between 3 months and 1 year (0.00 mm (CI -0.10; 0.11) or between 1 and 2 years (0.05 mm (CI -0.03; 0.13)). For the carpal component, there was no statistically significant TT between 3 months and 1 year (0.04 mm (CI -0.08; 0.16)) or between 1 and 2 years (-0.02 mm (CI -0.06; 0.03)).

At 2 years follow-up, the TT of the carpal and radius component was 0.35 mm (CI 0.12; 0.58) and 0.41 mm (CI 0.27; 0.55), respectively. The TR of the carpal and radius component was 2.4

degrees (CI 1.9; 3.0) and 2.5 degrees (CI 1.9; 3.1), respectively. Grip strength improved from 16 kg (CI 13; 19) preoperatively to 21 kg (CI 17; 26) at 2 years follow-up ($p<0.03$). Pain score at rest improved from 5.1 (CI 4.0; 6.3) preoperatively to 1.1 (CI 0.3; 1.8) at 2 years follow-up ($p=0.00$). Pains score during activity improved from 6.6 (CI 5.8; 7.4) preoperatively to 2.5 (CI 1.6; 3.5) at 2 years follow-up ($p=0.00$). The QDASH score improved from 82 points (CI 71; 92) preoperatively to 64 points (CI 51; 78) at 2 years follow-up ($p=0.02$). There were no radiological signs of component loosening or osteolysis. One patient had extensor tendon rupture and surgical reconstruction following a Darrach procedure and later received an APTIS total distal radioulnar joint arthroplasty. There were no infections.

Conclusion

At short-term follow-up, both the radius and carpal components of the Freedom wrist arthroplasty had stable fixation with TT similar to the Motec and ReMortion wrist arthroplasty. Patient-reported outcomes improved clinically significantly and complications were few and mainly related to distal radioulnar joint symptoms and secondary procedures. The Freedom wrist arthroplasty provided good results both in rheumatoid and osteoarthritis patients.

[1] Holm-Glad et al. A randomized controlled trial comparing two modern total wrist arthroplasties: improved function with stable implants, but high complication rates in non-rheumatoid wrists at two years. Bone Joint Journal 2022, Oct; 104-B(10):1132-1141.

Accuracy and Precision of CT-RSA Migration Measurements of the CapFlex PIP Prosthesis Compared to MBRSA: an Anatomic Specimen Study

R. Oomen[1], L.A. Koster[2], B.L. Kaptein[2], I.F. Blom[1,3], G.A. Kraan[1], N.M.C. Mathijssen[1]

1) Reinier Haga Orthopedisch Centrum, Zoetermeer, The Netherlands

2) Leids Universitair Medisch Centrum, department of orthopaedics, Leiden, The Netherlands

3) Reinier de Graaf Gasthuis, department of radiology, Delft, The Netherlands

Purpose

Measuring migration of prosthesis in small joints is a real challenge. The current gold standard to measure migration is Roentgenstereometric Analysis (RSA). RSA requires bone markers to measure implant migration. An upcoming method to measure migration is Computed Tomography based RSA (CT-RSA). This method does not require markers, and therefore avoids the difficulties of marker distribution in a small bone. However, the accuracy and precision of CT-RSA have not yet been assessed for migration analysis in small joints. The aim of this study is to assess the accuracy and precision of migration measurements of the CapFlex PIP prosthesis using CT-RSA and compare the results with MBRSA.

Methods

An anatomic specimen of the proximal and intermediate phalanges with an implanted CapFlex-PIP prosthesis (KLS Martin Group, Tuttlingen, Germany) was placed in a micromanipulator. The proximal phalanx was translated along the x-, y- and z-axis (0.0/0.1/0.2/0.3/0.5/0.7/1.0/1.5/2.0/2.5 mm) and rotated around the longitudinal axis (0.0/0.1/0.2/0.5/0.7/1.0/2.0/3.0/4.0/5.0°) in 10 manipulations each. Manipulations were applied for translations and rotations separately. At each position, a CT-scan and set of RSA radiographs were made. All CT-scans were analyzed with V3MA software (RSA*core*, LUMC, Leiden, The Netherlands) and all radiographs were analyzed with MBRSA software (RSA*core*, LUMC, Leiden, The Netherlands) to calculate translations and rotations of the components compared to the opposing bone. One analyst repeated the analysis after at least one month, and all analyses were performed by two analysts.

Results

No significant differences were found between the applied manipulation and measured migration for all V3MA variables and MBRSA variables, except for the y-axis translation in the distal component -0.023 mm (95%CI -0.004 – 0.050, p=0.005) measured with V3MA and for the x-axis translation in the proximal component 0.051 mm (95%CI -0.024 – 0.126, p=0.003) and the y-axis rotation in the distal component 1.465° (95%CI 0.090 – 2.841, p<0.001) measured with MBRSA. All variables measured with V3MA had a smaller precision interval compared to MBRSA, except for the Y-axis translation with a precision interval in the proximal component of 0.048 mm for V3MA and 0.033 mm for MBRSA and in the distal component of 0.026 mm for V3MA and 0.020 mm for MBRSA. Intra- and inter-rater reliability was higher for V3MA (ICC: 0.726 - 1.000 (p<0.001), IRR: 0.407 – 1.000 (p<0.001)) compared to MBRSA (ICC: 0.328 - 0.999 (p<0.001), IRR: 0.290 – 0.999 (p<0.001)).

Conclusion

This study concludes that V3MA has a better accuracy, precision, inter- and intra-rater reliability compared to MBRSA and is a valid method to measure migration patterns in the hand.

Quantification of fusion in cervical spine using induced displacement CT-RSA

Olof Sandberg*[1], Per Svedmark[2], Henrik Olivecrona[3]

*corresponding author [1]Sectra, Linköping, Sweden, olof.sandber@sectra.com [2]RKC, Stockholm, Sweden [3]Karolinska Institute, Stockholm, Sweden

Purpose

Anterior cervical discectomy and fusion (ACDF) is a common surgical procedure for the treatment of cervical degenerative disc disease and herniated discs. Cervical cages with integrated plates have been developed to enhance stability and reduce the risk of complications. The biomechanical properties of cervical cages with integrated plates have been evaluated in several studies either through computer simulations or by qualitative assessment of radiographs and these have found that the design provides increased stiffness (1-3). This study evaluates the fusion quantitatively in Vivo, using induced displacement CTs and CT-RSA at 1 year.

Methods

A prospective cohort of 40 patients was consecutively recruited from a single clinic between 2018 and 2019. The average age of the cohort was 47 years, with the most prevalent surgical level being C5-C6. All patients presented with unilateral or bilateral arm radiculopathy due to single-level root canal stenosis or cervical disc herniation. Exclusion criteria was myelopathy, osteoporosis, previous cervical surgery, or other neurological disease. The procedures were performed by five surgeons, each with extensive experience in cervical surgery spanning over 10 years, ensuring familiarity and expertise in the employed method.

Patients underwent a provocation CT scan at a 1-year follow-up. These were analyzed with CT-RSA (CTMA, Sectra, Linköping, Sweden). The output is quantification in degrees and millimeters in all directions, with rotation around X as our main reported variable as this is the main direction of the movement in the operated segment. Normally distributed data was presented with average and confidence interval (SD*t-value). Non-normal distributed data was presented with median and LQ and UQ. Interobserver variability was tested in 21 patients using intraclass correlation coefficient two way random in absolute agreement, reporting the lower 95% CI. The first observer (OHS) was experienced with the CT-RSA software while the second observer (PS) was new. Data was analyzed using SPSS.

Results

Absence from the CT analysis was noted in 2 out of the initially recruited 40 patients, necessitating their exclusion due to reoperations within the one-year follow-up period. Additionally, 8 patients declined participation in the one-year post-surgery CT provocation. No surgical complications occurred; all the patients were discharged from the clinic within one day post-operation.

The induced rotation around the X-axis was 2.7 degrees (95% CI 2.0 to 3.4). For the y and z rotation this was 0.08 degrees (Lower and upper quartile -0.18 and 0.82), and 0.05 degrees (-0.06 and 0.27), respectively. The translations in x, y, z were 0.01 (-0.1 and 0.13), -0.6 (-1.1 and -0.24), and -0.42 (-0.57 and - 0.2) mm respectively. Interobserver variability gave R-values with a lower 95% CI of 0,99, 0,86, 0,80 for xr, yr, zr respectively. For translation measurements the corresponding ICC for x, y, z were 0,76, 0,76, and 0,91 respectively.

Conclusion

The vast majority of patients displayed motion above 2 degrees, and the lower CI of the mean was 2 degrees we were able to exclude induced displacements smaller than 2 degrees from a 95% confidence interval, with excellent to good interobserver variation.

Denosumab decreases the subsidence of cementless tibial implants by suppression of bone resorption.

A randomized, double-blinded RSA study in 54 patients with 5 years follow-up

Karina Nørgaard Linde[1,2], Søren Rytter[1,2], Bente Langdahl[2,3], Frank Madsen[1], Maiken Stilling[1,2]

1: Department of Orthopedics, Aarhus University Hospital, Aarhus Denmark

2: Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

3: Department of Endocrinology and Internal Medicine, Aarhus University Hospital

Abstract

Purpose

Cementless tibial implants migrate initially until osseointegration. Denosumab, an antiresorptive, binds to RANKL and reduces the function and survival of osteoclasts resulting in a suppression of bone resorption. An animal study reported that denosumab enhanced fixation more potently than bisphosphonates. Additionally, a clinical study observed reduced migration of a cemented knee implant at the 1-year follow-up when treated postoperatively with denosumab. However, the effect of denosumab on cementless knee implants is unknown. We aimed to study the effect of postoperative injections of denosumab on the bone remodelling process and the fixation of a cementless tibial implant. We hypothesized that denosumab decreases the early migration of cementless tibial implants.

Methods

A prospective, double-blinded, randomized study including 54 patients operated with a total knee arthroplasty (TKA) using a cementless tibial implant (Regenerex). Patients were randomized to two injections subcutaneously (second postoperative day and 6 months postoperative) of denosumab (60mg) (Dmab group) or 1 ml NaCl (9mg/ml) (placebo group). The primary outcome was tibial implant migration, measured by radiostereometric analysis and evaluated by maximum total point motion (MTPM) and Y-translation (subsidence). Secondary outcomes were biochemical bone turnover markers (CTX, P1NP), and periprosthetic Bone Mineral Density (BMD) measured by dual-energy X-ray absorptiometry (DXA). RSA, DXA, and blood samples were obtained postoperative and at follow-up at 2 and 6 weeks, 3 and 6 months, and at 1, 2, and 5 years.

Results

At 1 year, the mean difference in MTPM between the Dmab and placebo groups was 0.42 mm (95%CI 0.00; 0.83, p=0.048). At 5 years, the mean difference in MTPM was 0.10 mm (-0.42; 0.63, p=0.705). The mean tibial implant subsidence at 5 years was -0.21 mm (95%CI: -0.41; -0.01) in the Dmab group and -0.51 mm (95%CI: -0.71; 0.32) in the placebo group, with a mean difference of 0.30 mm (95%CI 0.03; 0.58, p=0.031). Bone resorption (CTX) was significantly lower in the Dmab group than in the

placebo group during the first postoperative year ($p<0.001$). Bone formation (P1NP) was lower at 6 weeks, 6 months, and 1 year ($p<0.02$) but similar at 2 and 5 years ($p>0.61$). In general, periprosthetic BMD was higher in the Dmab group until 12 months follow-up, but similar thereafter ($p>0.151$).

Conclusion

Compared to placebo, two denosumab injections given with a 6-month interval after TKA surgery resulted in a decrease in MTPM at 1 year and a lower subsidence of cementless tibial implants at 5 years after surgery. Bone resorption measured systemically was suppressed and there was a pattern of a higher early postoperative periprosthetic BMD in the Dmab group than in the placebo group. However, periprosthetic BMD and CTX were similar after 12 months, indicating the treatment did not provide a lasting preservation of the periprosthetic BMD preservation.

Characters: 452 words

Association between bone mineral density and implant migration of cemented and cementless tibial implants

A prospective clinical cohort RSA study in 397 patients

Karina Nørgaard Linde[1,2], Bente Langdahl[2,3], Søren Rytter[1,2], Rob Nelissen[4], Maiken stilling[1,2]

[1]Department of Orthopaedics, Aarhus University Hospital, Denmark

[2]Department of Clinical Medicine, Aarhus University, Denmark

[3]Department of Endocrinology and Clinical Medicine, Aarhus University Hospital, Denmark

[4]Department of Orthopedics, Leiden University Medical Center, Leiden, The Netherlands

Abstract

Purpose

Aseptic loosening of tibial implants is a major cause of revision surgery. This study investigated the impact of preoperative systemic bone mineral density (BMD) on tibial implant migration in knee arthroplasty.

Methods

We conducted a prospective clinical cohort study of 397 patients (397 knees) operated between 2014 and 2018 with a unicompartmental knee arthroplasty (UKA) or a total knee arthroplasty (TKA). Cementless tibial implants were used in 210 patients (TKA n=78 and UKA n=132) and 187 received cemented implants (TKA n=83 and UKA n=104). Preoperative bone mineral density (BMD) was measured using DXA of the spine and hips. The lowest BMD was used to calculate the T-score and categorize patients into normal or low BMD groups. Postoperative tibial implant migration was assessed using radiostereometric analysis (RSA) at 1, 2, and 5 years, evaluated by maximum total point motion (MTPM). The primary outcome was the 1-year MTPM comparison between BMD groups. Secondary outcomes evaluated the T-score as a predictor of continuous migration (MTPM>0.2 mm between 1- and 2 years of follow-up).

Results

For cementless TKAs, no significant differences were found in mean MTPM between BMD groups throughout follow-up (1-year mean difference: 0.15 mm 95% CI -0.25; 0.55, P=0.461). Similar findings were observed for cemented TKAs (1-year mean difference: 0.12 mm 95% CI -0.25; 0.49), cementless UKAs (1-year mean difference: -0.21 mm 95% CI -0.51; 0.10), and cemented UKAs (1-year mean difference: -0.15 mm 95% CI -0.34; 0.04).

There was no significant association between bone mineral density and continuous migration. However, for cementless implants, a higher preoperative T-score was associated with a mean 23% (95% CI 0.55; 1.07, P=0.118) decrease in the odds of having an unstable implant.

Conclusions

Although no significant associations between BMD and migration were found, our findings showed less cementless tibial implant migration in the presence of a higher preoperative T-score, although this did not reach significance (p=0.118). No association was found between BMD and migration for cemented implants, suggesting that cemented fixation may provide greater stability for patients with low bone mass. These findings support the existing literature, and from a clinical perspective, this suggests that patients with lower BMD may benefit from cemented implants or targeted strategies to optimize BMD before or during surgery.

Characters: 369 words

Antiresorptive treatment reduces the subsidence of tibial implants. A prospective clinical RSA study of 961 patients

Mohammad Ali Karim[1,2], Karina Nørgaard Linde[1,2], Janni Kjærgaard Thillemann[1,2], Maiken stilling[1,2]
[1]Department of Orthopaedics, Aarhus University Hospital, Denmark
[2]Department of Clinical Medicine, Aarhus University, Denmark

Purpose
Implant loosening is a leading cause of implant failure, which is preceded by implant migration. To accommodate the expected increase in the elderly population, it is important to seek options to reduce the risk of pain, reduced function, and dependency, as well as complex and costly revision surgeries, related to implant loosening. Antiresorptive medications are used to prevent bone resorption and maintain bone density, which may reduce the migration of tibial implants. We aimed to investigate if treatment with antiresorptives reduces tibial implant migration.

Methods
We conducted a prospective clinical cohort study of 961 patients (961 knees) who underwent unicompartmental knee arthroplasty (UKA) or a total knee arthroplasty (TKA) between 2014 and 2018. All patients completed a detailed questionnaire regarding risk factors for osteoporosis/osteopenia before surgery. Patients were divided into two groups receiving antiresorptive treatment (treatment group) or not (untreated group).
The primary outcome was 1-year maximum total point motion (MTPM). Postoperative tibial implant migration was measured with radiostereometric analysis (RSA) at 1, 2, and 5 years and evaluated by MTPM and y-translation (subsidence/lift off) comparison between treatment groups. All analyses were adjusted for age, sex, and BMI.

Results
The mean age of the patient cohort was 68.1 years (range 18-93) and consisted of 398 males and 563 females. Of the 961 patients, 86 (8.9%) received antiresorptive treatment at the time of surgery.
Evaluation of all TKA and UKA implants combined (n=961), the mean 1-year MTPM in the treatment group was 1.12 mm (95% CI 0.90; 1.35), compared to 1.08 mm (95% CI 1.01; 1.14) in the untreated group (P=0.70). There was no significant difference in mean MTPM between the treated and untreated group throughout follow-up (P>0.93). Translation on the y-axis was significantly less in the treated group at all follow-ups (P >0.012). At 5 years, the mean y-translation in the treated group was 0.03 mm (95% CI -0.05; 0.10) compared to -0.10 mm (95% CI -0.13; -0.07) in the untreated group (P=0.003).
Focusing on cementless implants only (n=623), there was no statistically significant difference in y-translation between the treatment groups. However, there was a trend toward less y-translation in the treated group, with a mean 1-year subsidence of -0.15 mm (95% CI -0.30; 0.00), compared to -0.24 mm (95% CI -0.28; -0.19) in the untreated group (P=0.267).

Conclusion
Antiresorptive treatment did not significantly reduce tibial implant MTPM but was associated with lower tibial implant y-translation at all follow-ups when all types of implants were evaluated. This effect was not observed in the subgroup of cementless implants, although there was a trend toward reduced subsidence in the treated group.
As implant migration is a predictor of implant failure, antiresorptive treatment may have a protective effect against premature implant loosening in patients undergoing knee arthroplasty surgery.

These findings are based on preliminary data analyses. More detailed results will be explored ahead of the conference.

Title

Tibial component micromotion of a bicruciate-retaining total knee arthroplasty correlated with early inducible displacement

Authors

Kelly Mills, Simon van Laarhoven, Petra Heesterbeek

Sint Maartenskliniek, Nijmegen, the Netherlands

Purpose

In bicruciate-retaining total knee arthroplasty (BCR-TKA), retaining both cruciate ligaments requires a unique tibial component design. This design features smaller pegs that penetrate the bone less deeply, reducing the bone-implant surface compared to traditional TKA designs. This study aimed to evaluate tibial component fixation using RSA over a two year follow-up. These preliminary results present one-year RSA data and inducible displacement measurements at three months postoperatively to explore a potential association between early inducible displacement and implant micromotion. Identifying such an association could offer valuable indications of implant fixation failure.

Methods

All patients received the Journey II XR (Smith&Nephew, USA) BCR-TKA. RSA radiographs were made the day after surgery (baseline) and at 6 weeks, 3 months, 6 months and 1 year postoperatively. Tibial micromotion was calculated using model-based RSA software (v. 4.2014;RSAcore, the Netherlands). Precision measurements were done on double RSA examinations at 6 weeks follow-up. At 3 months follow-up standing RSA images were made in extension and 90° knee flexion, with objectified 50% weightbearing. Inducible micromotion was calculated for both the extension and flexion radiograph referenced to the supine RSA at 3 months follow-up. All micromotions were reported as Maximum Total Point Motion (MTPM). Thereby the translation along the longitudinal axis (Ty) and tibial tilt (Rx) are reported because these could be interesting directions for this type of implant (Mills et al., 2023). Multiple regression analyses were done with micromotion values (MTPM, Ty and Rx) at 1 year follow-up as independent variable and inducible micromotion at 3 months follow-up in extension and 90° knee flexion as dependent variables.

Results

A total of 25 patients were included, 13 females, 13 right knees, with a mean age at the time of surgery of 63.6 (±7.8) years. All values are reported as medians and interquartile ranges. At 1 year follow-up MTPM was 0.38 (0.29;0.62) mm and Ty and Rx were 0.07 (0.03;0.12) mm and -0.24 (-0.44;0.10), respectively. The precision of RSA measurements was 0.16 (0.12;0.20) mm, 0.06 (0.05;0.08) mm and 0.19 (0.12;0.23)°, respectively. The $\Delta MTPM_{6\text{-}12months}$ was 0.07 (-0.05;0.19) mm, with 5 patients exhibiting a $\Delta MTPM_{6\text{-}12months}$>0.2 mm. Inducible micromotion analysis showed MTPMs of 0.37 (0.26;0.44) mm and 0.43 (0.33;0.66) mm, Ty of -0.03 (-0.06;0.02) mm and 0.01 (-0.06;0.04) mm and Rx of 0.22 (0.09;0.46)° and -0.09 (-0.30;0.25)°, for standing RSA radiographs at 0 and 90° knee flexion, respectively. The regression analysis showed a significant association between tibial tilt (Rx) and inducible displacement Rx in 90° knee flexion at 3 months post-operatively (p=0.019).

Discussion

On average the patients showed relatively low amounts of micromotion, below the group threshold of $\Delta MTPM_{6\text{-}12months} < 0.2$ defined by Pijls et al (2018). However, there are 5 patients with higher levels of micromotion. The significant association between inducible displacement Rx in 90° knee flexion at 3 months follow-up and Rx micromotion at 1 year follow-up may offer insights into potential future implant behaviour, helping to identify patients at risk of loosening. Further follow-up is needed to confirm whether early inducible displacement can predict later implant instability.

References

- Pijls BG, Plevier JWM, Nelissen R. RSA migration of total knee replacements. Acta Orthop. 2018;89(3):320-8.
- Mills K, Wymenga AB, Benard MR, Kaptein BL, Defoort KC, van Hellemondt GG, et al. Fluoroscopic and radiostereometric analysis of a bicruciate-retaining versus a posterior cruciate-retaining total knee arthroplasty: a randomized controlled trial. Bone Joint J. 2023;105-B(1):35-46.

Construct stability of revision total knee arthroplasty with tibial cones: 2-years of radiostereometric analysis (RSA)

Petra Heesterbeek, Kelly Mills, Maartje Belt, Gijs van Hellemondt

Sint Maartenskliniek, Nijmegen, The Netherlands

Purpose
In (re-)revision total knee arthroplasty (TKA), cones can be used to ensure sufficient fixation of the prothesis in the bone in case of suboptimal metaphyseal bone stock. Together with stems, cones can reduce bone-implant interface stresses and provide additional prosthetic surface for implant fixation. This study aims to investigate the fixation of these constructs in the tibia bone, using radiostereometric analysis (RSA).

Methods
All 25 included patients underwent revision TKA surgery with a tibial cone (Smith&Nephew), 2 press-fitted and 23 cemented tibial stems. Intraoperative inserted tantalum markers formed a 3D-tibia-bone-model for RSA analysis. Combined with a 3D CAD-model of the tibia component, the micromotion of the implants with respect to the bone was calculated on each RSA radiograph (biplanar), using model-based RSA analysis (MB-RSA). The stability of the implant was defined as total translation (TT) and total rotation (TR) of the tibial component with respect to the 3D-tibia-bone-model. Radiographs were made and analyzed post-operative (baseline), after 6 weeks, 3 months, 6 months, 1 and 2 years (n=19, so far). Clinical results were evaluated using the Oxford Knee Score, KOOS-PS, Knee Society Score, VAS pain and VAS satisfaction.

Results
Median TT at 1 year was 0.32 mm (IQR 0.24-0.75), with 4 implants with TT>1 mm, median TR was 0.58˚ (IQR 0.32-0.95) with 6 implants rotating >1˚. Median TT at 2 years was 0.33 mm (IQR 0.20-0.65) with 3 implants with TT>1mm, median TR was 0.51˚ (IQR 0.39-0.85), with 4 implants rotating >1˚. One patient had re-revision after 1 year for loosening, and 1 had knee instability (insert exchange). Clinical scores at 2 years were: VAS pain 4 (IQR 1-6), VAS satisfaction 6.5 (IQR 5-9), OKS 31 (IQR 21-41), KSS-clinical 81 (IQR 62-99) and functional 60 (IQR 50-80), and KOOS-PS was 38.6 (27.5-48.5).

Conclusion
So far, results on group level show a stable fixation up until 2 years postoperative, although there are outliers with more micromotion. One patient had a repeat-revision TKA for loosening, not evidently related to micromotion as measured with MB-RSA. At the time of the conference, the complete analysis of 2-years results will be available.

Evaluation of the association between inducible micromotion of unicompartmental knee arthroplasty and patient-reported outcomes. A static and dynamic RSA study.

Jonathan Hugo Jürgens-Lahnstein[1,2,3], Emil Toft-Petersen[1,2,3], Søren Rytter[1,2,3], Maiken Stilling[1,2,3]

[1] *AutoRSA Research Group, Orthopaedic Research Unit, Aarhus University Hospital, Aarhus, Denmark*

[2] *Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*

[3] *Department of Orthopedic Surgery, Aarhus University Hospital, Aarhus, Denmark*

Purpose

About 20% of patients receiving knee arthroplasty experience pain after surgery and are not satisfied with the functional result. The reason has been difficult to establish but may have a biomechanical explanation. We aimed to investigate inducible micromotion (IMM) patterns of patients with high and low improvement following unicompartmental knee arthroplasty (UKA) using static and dynamic radiostereometric analysis (RSA).

Methods

Patients with at least 5 years of follow-up were identified from the in-hospital RSA database. All patients received a cemented or uncemented Oxford unicompartmental knee arthroplasty (UKA). The mean Knee Injury and Osteoarthritis Outcome Score (KOOS) pain subscale increased from preoperative to 2 years by 39 (18). High-improvers were defined as patients with KOOS pain subscale above mean +1 SD (58), and low-improvers as patients with KOOS pain subscale below mean -1 SD (20). Fifty-eight patients are planned for inclusion and will be categorized into high (n=29)- and low (n=29)-improvers. All patients received a CT scan of the hips, knees and ankles and performed supine and full weight-bearing static RSA images and step-up/step-down dynamic RSA recordings (15 frames/second). The step-up/step-down motion was divided into 11 phases based on knee flexion to align motion between subjects.

Results

These are preliminary results of 20 patients (10 females) with a mean age of 76 (range 60 - 86) at a mean follow-up of 8 years (range 6 - 10) since primary surgery. The KOOS pain subscale at follow-up was 98(SD 2, n=14) for high-improvers and 90 (SD 16, n=6) for low-improvers. For supine to weight-bearing (static RSA), low-improvers showed 0.5° (95% CI: 0.05–0.95) less internal rotation and 0.29 mm (95% CI: -0.01–0.6) less anterior translation than high-improvers. During the step-up/step-down exercise (dynamic RSA), low-improvers showed 0.42 mm (95% CI: 0.06–0.79) more lift-off during step-up and 0.38 mm (95% CI: 0.00–0.75) more lift-off during step-down than high-improvers.

Conclusion

These preliminary results suggest differences in IMM patterns between patients with high- and low-improvement following primary UKA, which may be explained by differences in the stability of the implant-bone interface. Furthermore, the study indicates a difference

between static and dynamic IMM, which need further investigation by i.e. different loading and exercises.

Model-based wear measurement on plain radiographs enables early monitoring of TKA inlay wear

Emonde C[1] , Hurschler C.[1], Eggers M.-E.[2], Wichmann M.[2], Ettinger M.[1], Denkena B.[2]

[1] Laboratory for Biomechanics and Biomaterials, Department of Orthopaedic Surgery Hannover Medical School – Annastift DIAKOVERE, Anna-von-Borries-Strasse 1-7, 30625 Hannover, Germany

[2] Institute of Production Engineering and Machine Tools, Leibniz University Hannover, An der Universität 2, 30823 Garbsen, Hannover, Germany

Introduction

Wear of the ultra-high-molecular-weight polyethylene (UHMWPE) inlay significantly compromises the long-term success of total knee arthroplasty (TKA), increasing the risk of early implant failure and accelerating joint degeneration, particularly in younger patients [1]. According to the German Arthroplasty Registry, isolated replacement of the inlay component accounted for 21% of TKA revisions performed in 2022 [2]. Current clinical methods for assessing inlay wear are unreliable in detecting sub-millimetre wear and yield high errors > 1 mm [3], [4].

Purpose

This study investigates the accuracy and precision of model-based wear measurement (MBWM) in estimating the minimum thickness and in-vitro linear wear of standard TKA inlays using plain radiographs. This technique utilises 2D-to-3D registration to reconstruct the 3D pose of implant components from a standard 2D radiograph and calculates the minimum relative separation between the femur and tibia components. A change in this thickness over time equates to linear wear.

Methods

Six standard inlays of thicknesses 10 mm, 14 mm & 16 mm (two per thickness) were milled from non-crosslinked UHMWPE1000. Each inlay was introduced between corresponding implant components in a phantom knee model set-up for radiographic imaging. Anteroposterior radiographs were acquired at flexion angles: 0°, 30° & 60° flexion for each inlay. Three of the inlays underwent in-vitro wear generation on a testbed and linear wear was similarly evaluated.

Accuracy was defined as the mean absolute error between MBWM-measured values and reference values measured using a coordinate measuring machine (CMM). Double MBWM analyses were performed and the 95% confidence interval (CI) was calculated to assess the method's precision. Calculations were performed for each condyle of the inlay (medial & lateral).

Results

The accuracy of inlay thickness measurements across all angles was 0.13 ± 0.09 mm medially and 0.14 ± 0.09 mm laterally. For linear wear, the accuracy was 0.09 ± 0.09 mm medially and 0.05 ± 0.04 mm laterally across the flexion angles. Significant differences in inlay thickness were found laterally between 0° and 30° of flexion (t-test, $p = 0.0002$). No significant differences in linear wear were found across flexion angles (one-way ANOVA, $p = 0.79$). The 95% confidence interval (CI) indicated a precision of ± 0.03 mm for repeated thickness and wear measurements on both condyles.

Conclusion

MBWM presents a reliable method for detecting TKA inlay wear clinically that is accurate and precise. Consistency in knee joint positioning during follow-ups is crucial for accurate estimations at consistent contact points.

References

[1] K. T. Kim, S. Lee, D. O. Ko, B. S. Seo, W. S. Jung, and B. K. Chang, "Causes of Failure after Total Knee Arthroplasty in Osteoarthritis Patients 55 Years of Age or Younger," *Knee Surg Relat Res*, vol. 26, no. 1, pp. 13–19, Mar. 2014, doi: 10.5792/ksrr.2014.26.1.13.

[2] A. Grimberg, J. Lützner, O. Melsheimer, M. Morlock, and A. Steinbrück, *The German Arthroplasty Registry (EPRD) Annual Report 2023*. DE: EPRD gGmbH, 2024. Accessed: Jan. 03, 2025. [Online]. Available: https://www.eprd.de/en/about-the-eprd/news/article/annual-report-2023
[3] M. G. Teeter *et al.*, "Radiostereometric Analysis Permits In Vivo Measurement of Very Small Levels of Wear in TKA," *Clin Orthop Relat Res*, vol. 477, no. 1, pp. 80–90, Jan. 2019, doi: 10.1097/CORR.0000000000000399.
[4] E. A. van IJsseldijk, E. R. Valstar, B. C. Stoel, R. G. H. H. Nelissen, and B. L. Kaptein, "A model-based approach to measure the minimum joint space width of total knee replacements in standard radiographs," *Journal of Biomechanics*, vol. 45, no. 12, pp. 2171–2175, Aug. 2012, doi: 10.1016/j.jbiomech.2012.05.012.

Acknowledgements

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – SFB/TRR-298-SIIRI – Project-ID 426335750.

Title: Comparison of the in vivo stability of 2 cementless TKA designs using CT micromotion analysis - A randomized controlled trial

Acronym of the study: Cless*TKA*

Authors: Fredrik Bru[1, 2]; Lars H.W. Engseth [2, 3]; Are Hugo Pripp [4, 5] ; Anselm Schulz [6] ; Tommy Frøseth Aae [1, 7]; Stephan M. H. Röhrl [2, 3] ; Otto Schnell Husby [1, 7] ;Frank-David Øhrn [1, 7]

[1] Orthopaedic Department, Kristiansund Hospital, Møre and Romsdal Hospital Trust, Kristiansund, Norway

[2] Division of Orthopaedic Surgery, Oslo University Hospital Ullevål (CIRRO), Oslo, Norway

[3] Faculty of Medicine, University of Oslo, Oslo, Norway

[4]Oslo Centre of Biostatistics and Epidemiology, Research Support Services, Oslo University Hospital, Oslo, Norway.

[5]Faculty of Health Sciences, OsloMet – Oslo Metropolitan University, Oslo, Norway.

[6] Department of Radiology and Nuclear Medicine, Oslo University Hospital Ullevål, Oslo, Norway

[7] Faculty of Medicine and Health Sciences, Department of Neuromedicine and Movement Science (INB), NTNU Norwegian University of Science and Technology, Norway

Acronym of the study: Cless*TKA*

Word count: 484

Abstract:

Purpose: A medial pivot total knee arthroplasty, with promising kinematics and clinical results, was introduced to the market several years ago [1]. A novel 3D printed cementless version of this implant is now introduced to the market. The aim of this study was to analyze the early *in vivo* stability over time of this new total knee arthroplasty and compare it with that of a well-documented implant, using CT-RSA[2, 3]. The H_0 was that there was no difference in micromotion between the implants.

Methods: In this multiple blinded randomized controlled trial we compared the 3D printed cementless medial pivot knee (GMK Sphere 3D metal, Medacta International, Switzerland) with the Triathlon Tritanium CR (Stryker, Mahwah, USA) [4, 5]. The randomization was performed by an online service with varying block sizes and stratification by sex. The patients and the staff at the hospital ward including the nurses and physiotherapists were blinded for the allocation, as were the co-authors and biostatistician. The study recruited 50 patients, 25 in each group, at Kristiansund Hospital, Norway. Patients were allocated to either the study (GMK Sphere 3D Metal) or control (Triathlon Tritanium CR) groups. All surgeries were performed using mechanical alignment between January and June 2023 by two experienced surgeons always working together (FDØ, OSH). CT acquisitions were performed with a GE Revolution CT scanner (GE Healthcare, Chicago, USA) after mobilization and within 2 days postoperatively (n=50) and after 3 and 12 months (n=50) with an effective radiation dose of 0.06 mSv. The CT-RSA migration analysis was performed using the CTMA software (Sectra, Linköping, Sweden). The primary endpoint was maximum total point motion (MTPM) of the tibial implant, the secondary endpoints were transversal, internal and varus rotations and medial, proximal and posterior translations in the center of mass. Differences in translations and rotations were calculated using a linear mixed model analysis with a p-value < 0.05 considered significant.

Results: The *mean* MTPM (95% CI) at 3 months of was 0.56 (0.20-0.92) for Tritanium and 0.78 (0.42-1.13) for GMK Sphere with mean difference 0.22 (-0.29 to 0.72), p= 0.4. For 1 year, the results were 0.58 (0.22-0.93) for Tritanium and 0.78 (0.43-1.1) for GMK Sphere with mean difference 0.21 (-0.30 to 0.72) and p= 0.24. The mean transversal, internal and varus rotations (95% CI) at 1 year postoperatively were for Tritanium/GMK Sphere: -0.43 (-0.07 to

0.92)/ -0.22 (-0.71 to 0.28, p=0.07), 0.21 (-0.03 to 0.46)/-0.07 (-0.26 to 0.24, p=0.95) and 0.04 (0.09 to 0.18)/ -0.16 (-0.29 to-0.02, p=0.04). The medial, proximal and posterior translations at 1 year postoperatively were -0.02 (-0.06 to 0.02)/ 0.03 (-0.01 to 0.07, p=0.1), -0.07 (-0.1 to -0.02)/ -0.05 (-0.09 to -0.01, p=0.6) and -0.12 (-0.27 to 0.03)/ -0.28 (-0.43 to -0.13, p=0.1), respectively.

Conclusion: The results of the study show that the mean micromotions and rotations of the tibial components of GMK Sphere 3D Metal and Triathlon Tritanium did not differ significantly up to 1 year.

References

1. Øhrn FD, Lian Ø B, Tsukanaka M, et al. Early migration of a medially stabilized total knee arthroplasty : a radiostereometric analysis study up to two years. *Bone Jt Open*. 2021;2(9):737-44.

2. Engseth LHW, Schulz A, Pripp AH, et al. CT-based migration analysis is more precise than radiostereometric analysis for tibial implants: a phantom study on a porcine cadaver. *Acta Orthop*. 2023;94:207-14.

3. Øhrn FD, Engseth LHW, Pripp AH, et al. Dose reduction does not impact the precision of CT-based RSA in tibial implants: a diagnostic accuracy study on precision in a porcine cadaver. *Acta Orthop*. 2023;94:550-44.

4. Hasan S, van Hamersveld KT, Marang-van de Mheen PJ, et al. Migration of a novel 3D-printed cementless versus a cemented total knee arthroplasty: two-year results of a randomized controlled trial using radiostereometric analysis. *Bone Joint J*. 2020;102-b(8):1016-24.

5. van der Lelij TJN, Marang-van de Mheen PJ, Kaptein BL, et al. Continued Stabilization of a Cementless 3D-Printed Total Knee Arthroplasty: Five-Year Results of a Randomized Controlled Trial Using Radiostereometric Analysis. *J Bone Joint Surg Am*. 2023.

The importance for precision to harmonize CT measurements in migration studies

A randomized controlled clinical trial

E. Kristoffersson[1], O. Sandberg[2], V. Otten[1]

[1] Department of Diagnostics and Intervention, Umeå University, Umeå Sweden; [2] Sectra AB, Linköping, Sweden

Purpose

High precision migration studies can be used to evaluate the performance of new implants in small groups of patients with a relatively short observation period. CT-based migration measurements have shown equally high precision compared to conventional RSA for measuring migration of cemented cups. Nevertheless, precision of migration and wear might be influenced by both different CT machines and algorithms used but to what extent is not yet fully studied.

The aim of this study was to investigate the impact on precision in CT-based RSA under optimal versus suboptimal CT-imaging conditions on uncemented cups in a prospective randomized clinical investigation. We hypothesize that the conditions will influence precision and that using similar conditions will prove the be superior.

Methods

70 patients receiving uncemented THA were recruited and randomized into two groups to undergo double follow-up CT scans under either optimal or suboptimal CT-imaging conditions at 1 year follow-up. For optimal conditions we used the same CT machine and same algorithms for the double examinations and for suboptimal conditions two different CT machines, different algorithms and different image resolution was used. In the first group CT images were reconstructed with and without metal artifact reduction (MAR) and with and without extended CT scale (ECTS), forming four subgroups to identify the most optimal settings. In the second group, different resolutions were established using either bilateral image framing resulting in lower resolution or unilateral image framing, yielding two subgroups. CTMA (Sectra, Linköping, Sweden) software was used to measure migration between the two CT scans, i.e. precision.

Results

The highest precision was obtained from the group undergoing double examination on the same CT machine using both MAR and ECTS, with a precision for cranial translation mean 0,03 mm (SD 0,03, CI 95% 0,02 to 0,04 mm) and total translation for maximum total point motion (MTPM) mean 0,11 mm (SD 0,05, CI 95% 0,10 to 0,13 mm) compared to the lowest precision from the suboptimal group using bilateral image framing (low resolution) resulting in mean cranial translation 0,12 mm (SD 0,08, CI 95% 0,09 to 0,15 mm) and mean total translation in MTPM 0,61 mm (SD 0,35, CI 95% 0,48 to 0,74 mm).

Conclusion

Different CT machines and algorithms between scans in migrations measurements result in decreased precision. We conclude that harmonizing CT setups in migration studies is important to obtain optimal precision.

Five Year Follow-Up of a Gap Balancing and Measured Resection Surgical Technique with Radiostereometric Analysis and Weight-Bearing Computed Tomography

Rebecca A. Hext, Purnima Sainani, James L. Howard, Brent A. Lanting, Matthew G. Teeter

Purpose: Total knee arthroplasty (TKA) is a successful procedure to decrease pain and restore knee function. Two common surgical approaches, gap balancing (GB) and measured resection (MR) both aim to achieve these goals, but they remain debated. A previous study has found comparable one-year migration between these surgical techniques with radiostereometric analysis (RSA). Our primary objective is to compare implant migration up to five years post-operation between those previously randomized to a GB or MR group. Weight-bearing computed tomography (WBCT) has been gaining traction in orthopaedics due to its ability to assess multiple parameters with a single radiation exposure. The secondary objective is to compare femoral component rotation, anterior tibial translation (ATT), and wear between these two groups.

Methods: Participants (n=18) were recruited in 2017-2018 to undergo TKA with either a GB (n = 9) or MR (n = 9) surgical technique. Supine RSA exams were acquired at two weeks, six weeks, three months, six months, one year, and five years post-operation to assess longitudinal migration. A standing RSA exam was also acquired at two weeks, one year, and five years post-operation to assess wear. At five years post-operation standing (full weight-bearing) WBCT exams were acquired. An open-source segmentation software (Slicer.org) was used to measure femoral component rotations and ATT. For femoral component rotations, the angle was measured between a line through the epicondyles, and another along the posterior border of the femoral condyles in the axial view. ATT was measured between the posterior borders of the tibial baseplate and medial or lateral femoral condyle. Wear was measured using implant component positions from the standing RSA exams, and a software identified the low point of the medial or lateral condyle in relation to the tibial baseplate.

Results: Tibial component migration rate between one and five years was 0.053 mm/year and 0.041 mm/year, respectively, for the GB and MR groups. Medial ATT was 10.10 ± 2.31 mm for the GB group, and 10.89 ± 4.11 mm for the MR group ($p = 0.644$). Lateral ATT was 8.67 ± 2.69 mm and 9.65 ± 2.17 mm for the GB and MR groups, respectively ($p = 0.435$). The GB group had 1.89 ± 2.38°, and the MR group had 1.31 ± 2.18° of external femoral component rotation ($p = 0.60$). Mean wear on the medial condyle between one and five years post-operation increased from 0.81 ± 1.35 mm to 1.63 ± 2.51 mm for the GB group and from 1.14 ± 2.73 mm to 1.75 ± 2.34 mm for the MR group. For the lateral condyle, wear increased from 1.15 ± 1.64 mm to 2.16 ± 1.73 mm for the GB group and from 1.27 ± 1.32 mm to 2.85 ± 1.16 mm for the MR group.

Conclusions: There were no significant differences between the GB or MR surgical technique for all measurements with WBCT. Both groups had migration values within safe threshold ranges. These results indicate promising outcomes with either surgical technique to achieve consistent implant alignment, placement, and knee kinematics.

Longitudinal assessment of impingement risk following total hip arthroplasty through the direct anterior approach

Shahnaz Taleb,[1,2] Jordan Broberg,[3] Jennifer Polus,[2] Brent Lanting,[4] Matthew Teeter[1,2]

1. School of Biomedical Engineering, Western University, London, Ontario, Canada
2. Imaging Research Laboratories, Robarts Research Institute, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada
3. Department of Orthopaedics, University of British Columbia, Vancouver, BC, Canada
4. Division of Orthopaedic Surgery, Department of Surgery, London Health Sciences Centre, ON, Canada

Purpose: Component-on-component impingement following total hip arthroplasty (THA) may lead to many post-operative complications, such as limited range of motion, component loosening, pain, increased wear, and even implant failure. Unfortunately, due to the dynamic nature of impingement and the limited measurement methodologies, the prevalence of impingement in non-failed total hips is largely unknown. Furthermore, it is known that early migration of implant components does occur following THA, which may potentially impact post-operative impingement measurements. Whether the risk of impingement varies with time is currently unknown. The objective of this study is therefore to evaluate component-on-component impingement risk in patients who have undergone THA over a 5-year post-operative timeline and to evaluate positional impact by comparing impingement risk in the supine and standing position.

Methods: Twenty-four participants were recruited pre-operatively and were followed for a five-year period. Participants underwent THA through the direct anterior approach, and all received the same implant system. Participants completed radiostereometric analysis (RSA) examinations in the supine position on the day of surgery, at 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months, 1 year, 2 years, and 5 years post-operation. Impingement risk was calculated by measuring the closest distance between the femoral stem and the polyethylene liner based on the 3-dimensional poses extracted from RSA. A threshold of 1 mm was defined to classify impingement, with distances approaching 1 mm being considered at higher impingement risk.

Results: Mean neck-liner distance in the supine position were 9.25 ± 1.28 mm at DOS, 9.20 ± 1.32 mm at 2 weeks, 9.21 ± 1.33 mm at 6 weeks, 9.13 ± 1.20 mm at 3 months, 9.14 ± 1.24 mm at 6 months, 9.20 ± 1.30 mm at 1 year, 9.26 ± 1.30 mm at 2 years, 9.01 ± 1.18 mm at 5 years. In the neutral standing position at 5 years, mean neck-liner distance was 7.70 ± 1.80 mm. No significant differences were found between neck-liner distances at any of the timepoints in the supine position. Neck-liner distances were significantly lower ($p < 0.001$) in the neutral stand position when compared to the supine position at any time point. No differences ($p = 0.222$) were reported between participants who received a collared and collarless stem, with means of 9.32 ± 0.60 mm and 8.70 ± 0.36 mm, respectively. Neck-liner distances were significantly lower ($p < 0.0001$) in participants who received a 32 mm femoral head (8.09 ± 0.60 mm) as compared to 36 mm (10.10 ± 0.34 mm).

Conclusion: Our findings indicate that component-on-component impingement risk remains stable in the supine position over 5 years. However, when moving from a supine to standing position, participants were at a higher risk of impingement, suggesting that weight-bearing evaluations are critical for assessing post-operative impingement. Additionally, smaller femoral head sizes are associated with a higher impingement risk, emphasizing the importance of appropriate component sizing in THA. This study contributes to a growing body of evidence supporting dynamic and individualized approaches to optimizing THA outcomes.

CT-based radiostereometric analysis (CT-RSA) Validation: *in vitro* precision of Volumetric Matching Micromotion Analysis (V3MA) and impact of image segmentation for a femoral prosthesis in TKA

Jessie E. Robertson[1,2], Bart L. Kaptein[1]

[1]Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

[2]Biomedical Engineering Program, University of Manitoba, Winnipeg, Canada

Purpose:

CT-RSA is a new method of tracking orthopaedic implant migration using CT images. CT-RSA has the potential to replace traditional radiostereometric analysis (RSA) methods as it does not require implanted markers or a specialized imaging apparatus. Volumetric Matching Micromotion Analysis (V3MA, RSAcore) is a CT-RSA software recently developed in Leiden, The Netherlands. This software has not yet been validated for determining femoral knee prosthesis migration. Furthermore, this software relies on the use of 3D models created using image segmentation. The impact of image segmentation methods on migration analysis has not been thoroughly investigated. The aim of this study was to determine the precision of V3MA in calculating femoral knee prosthesis migration in a cadaveric dataset, and to evaluate the effects of the image segmentation process on migration precision.

Methods:

CT-scans were obtained for 4 different cadaver bone sets in 5 different positions, each with a femoral knee prosthesis cemented to the femur; CT migration data was obtained using V3MA. RSA radiographs were previously collected for 3 of these sets in 7 different positions, and migration data was obtained using Model-Based RSA (MBRSA, RSAcore). This resulted in 16 migration measurements for V3MA (baseline comparison) and 21 migration measurements for RSA (pairwise comparison). The precision of V3MA and RSA was characterized by the standard deviation (SD) of the femoral component migration. Migration metrics included translations and rotations in 3 planes, and summary metrics including total translation (TT), total rotation (TR) and maximum total point motion (MTPM). To evaluate image segmentation, multiple different segmentation methods were used to create the 3D models for the analysis; segmentation methods included semi-automated, manual, ideal, and non-ideal methods. To compare image segmentation methods, descriptive statistics and Levene's test were used.

Results:

The precision of V3MA for femoral component migration was between 0.01-0.05 mm for translations, and 0.01-0.05 degrees for rotations. The precision of RSA was between 0.02-0.07 mm for translations and 0.04-0.14 degrees for rotations. V3MA was found to have equal or better precision in all metrics except y-translation (distal-proximal translation) where RSA had precision of 0.02 mm compared to 0.05 mm for V3MA.

For image segmentation, dilation of the femur bone was the method that achieved the best results for the majority of migration metrics. The precision of all methods was reduced with reduced image resolution. Precision for TT (range 0.01-0.03 mm) and MTPM (range 0.02-0.04 mm), was not different for different methods. However, for TR (range 0.01-0.02 degrees), Levene's test indicated that the different methods had different precisions, even though these differences were small.

Conclusion:

This study showed that CT-RSA is feasible using V3MA for calculating femoral prosthesis migration. V3MA had comparable precision to RSA and was minimally affected by the segmentation method. All segmentation methods produced precise results with migration values close to zero which was the ground truth for this dataset.

2y CT-RSA results in revision total hip patients – the PROUD study

Olof Sandberg[1], Michael Axenhus[2,3] Jörg Schindler[4], Olof Sköldenberg[2,3]

[1]Sectra, Linköping, Sweden, [2]Department of Orthopaedic Surgery, Danderyd Hospital, Stockholm, Sweden , [3] Department of Clinical Sciences at Danderyd Hospital, Karolinska Institutet, Stockholm, Sweden, [4]Department of Orthopaedics, Linköping University Hospital, Sweden

Introduction:
Total hip arthroplasty (THA) is highly successful, but revision surgeries for aseptic loosening of the acetabular component pose challenges in implant longevity. CT-RSA enables simpler measurements of implant migration in Vivo. This study evaluates the implant stability in hip revision surgeries over 2 years.

Methods:
This multi-center, prospective cohort study included 21 patients undergoing revision surgery for aseptic loosening of the acetabular component and CT imaging at post-op and at 24m. The estimated average effective dose for each low-dose scan was approximately 0,3 mSv.

Implant migration was measured using CT-based micromotion analysis (CTMA, Sectra, Sweden) and presented with median (lower quartile, upper quartile).

Results:
4 patients were excluded from the analysis, 2 were lost to follow up and 2 had no 2y CT-images. The MTPM was 0.87 mm (0.47, 2.34) while the proximal movement of the center of the cup opening was 0.32 mm (0.08, 0.96). The anterior tilt was -0.01 degrees (-0.37, 0.44).

Conclusion:

CTMA was able to analyse the migration data. The magnitude of the migration was comparable to that of the literature (Klerken et al 2015).

Preliminary Results of the Accuracy of CT-RSA of the TOUCH® Dual Mobility TMC Prosthesis: migration measurements in an anatomic specimen study

R. Oomen[1], L.A. Koster[2], B.L. Kaptein[2], I.F. Blom[1,3], G.A. Kraan[1], N.M.C. Mathijssen[1]

1) Reinier Haga Orthopedisch Centrum, Zoetermeer, The Netherlands

2) Leids Universitair Medisch Centrum, department of orthopaedics, Leiden, The Netherlands

3) Reinier de Graaf Gasthuis, department of radiology, Delft, The Netherlands

Purpose

In a small joint such as the trapeziometacarpal (TMC) joint, measuring migration is still a challenge. The current gold standard to measure migration is Roentgenstereometric Analysis (RSA), which requires the implantation of bone markers to measure implant migration. An upcoming method to measure migration is Computed Tomography based RSA (CT-RSA). This method avoids the difficulties of marker distribution, in a small bone such as the trapezium as it does not require the implantation of bone markers. However, the accuracy of CT-RSA has not yet been assessed for migration analysis of the TMC implant. The aim of this study is to validate the accuracy to measure migration of a TMC prosthesis using CT-RSA and compare this accuracy to the accuracy of model-based RSA.

Methods

An anatomic specimen of the trapezium and first metacarpal bones with an implanted TOUCH® TMC prosthetic (KeriMedical, Geneva, Switzerland) was positioned in a micromanipulator. The first metacarpal was translated in 9 steps along the x-, y- and z-axis until 2.5 mm and rotated in 9 steps around the longitudinal y-axis until 5.0°. Manipulations were applied for translations and rotations separately. At each position, a CT-scan (Canon Aquilion one scanner, slice thickness 0.5 mm, increments 0.25 mm, detector coverage 160 mm, Single Energy Metal Artifact Reduction) was made. All images were analyzed with V3MA software (RSA*core*, LUMC, Leiden, The Netherlands) to calculate translations and rotations of the cup and stem compared to the opposing bone. Bland-Altman analysis was done to calculate mean differences and 95% limits of agreement (LOA) between measured and applied translations and rotations.

Results

Mean differences of translations along the x-axis were -0.017mm [95%LOA -0.081; 0.047] for the cup and were -0.005mm [95%LOA -0.077; 0.068] for the stem, along the y-axis were -0.010mm [95%LOA -0.024; 0.004] for the cup and were -0.001mm [95%LOA -0.024; 0.022] for the stem, and along the z-axis were -0.009mm [95%LOA -0.027; 0.010] for the cup and were 0.027mm [95%LOA -0.017; 0.070] for the stem. The mean differences of rotations along the longitudinal-axis were -0.027° [95%LOA -0.782; 0.728] for the cup and were -0.112° [95%LOA -0.462; 0.238] for the stem. The mean differences of the rotations are higher compared to the translations and have a wider 95%LOA. This indicates that the accuracy for rotation is lower, which might be explained by the rotation symmetrical nature of the prosthesis. Comparison to model-based RSA could not be made yet.

Conclusions

Preliminary results show that V3MA is an accurate method to determine translation in a small joint such as the TMC. For rotations, the accuracy is lower, although still sufficient.

Migration in unicompartmental knee arthroplasty with the Persona® Partial Knee: a radiostereometric study with 5 years of follow-up

J.H. Pasma[1], B. Hesseling[1], I.F. Blom[1,2], D.D. Niesten[3], H. Verburg[1], N.M.C. Mathijssen[1]

[1]Reinier Haga Orthopedisch Centrum, Zoetermeer, the Netherlands

[2]Department of Radiology, Reinier de Graaf Gasthuis, Delft, the Netherlands

[3]Department of Orthopedics, Bergman Clinics, Rotterdam, the Netherlands

Purpose

In unicompartmental knee arthroplasty (UKA), aseptic loosening is one of the most common indications for revision surgery, which is mainly caused by migration. In this study, we investigated the migration and stability of the Persona® Partial Knee (PPK, Zimmer Biomet, Warsaw, IN), both the femoral and tibial component, during 60 months and evaluated the clinical results.

Methods

In this prospective cohort study, 26 primary PPKs were implanted. RSA radiographs were obtained in supine position direct postoperatively and at 6 weeks, 6 months, 1, 2 and 5 years after surgery. Migration of the tibial and femoral component was calculated using model-based radiostereometric analysis (mRSA) in terms of translations and rotations. Double examination was performed at 1 year follow-up to calculate the precision. To evaluate the clinical results, PROMs (NRS pain, KOOS-PS, OKS, EQ-5D) were registered. Linear mixed models were used to test whether there are significant migrations or changes in PROMs over time.

Results

At 5 years postoperatively, we found a translation of <0.21 mm and rotation of <0.75 degrees in all directions for both the tibial and femoral component.

The tibial component shows statistically significant migration at 5 years follow-up compared to baseline in all directions, except the translation along the z-axis. The translation along the y-axis and rotation about the z-axis were outside the precision interval. Compared to 2 years follow-up, the tibial component shows an increased total translation and an increased total rotation at 5 years.

The femoral component only shows a significant rotation along the x- and z-axes at 5 years follow-up, which were outside the precision interval. Between 2 and 5 years follow-up, the femoral component shows a stable migration. All PROMs remains stable between 2 and 5 years follow-up.

Conclusion

The Persona® Partial Knee shows low migration of both the tibial and femoral component at 5 years follow-up. The femoral component was stable between 2 and 5 years, while the tibial component still migrated. Information about the long-term migration is needed to gain more insight in the migration patterns of UKA and the relation between the migration and long-term results.

CT-RSA is a suitable replacement for RSA in evaluating migration of tibial implants – phantom study of accuracy

Lars Engseth[1,2], Frank-David Øhrn [3,4] Stephan M. Röhrl[1,2]

[1]Division of Orthopaedic Surgery, Oslo University Hospital Ullevål (CIRRO), Oslo, Norway
[2]Faculty of Medicine, University of Oslo, Oslo, Norway
[3]Orthopaedic Department, Kristiansund Hospital, Møre and Romsdal Hospital Trust, Kristiansund, Norway
[4] Department of Neuromedicine and Movement Science (INB), Faculty of medicine, NTNU - Norwegian University of Science and Technology, Trondheim, Norway

Purpose
Radiostereometric analysis (RSA) has long been the gold standard for assessing micro-motions in orthopedic implants. However, computed tomography-based RSA (CT-RSA) offers a potentially transformative approach by eliminating the need for radiographic markers and standard RSA-setups. CT-RSA has shown high precision (1-5) in the hip, shoulder and knee, but accuracy data for CT-RSA compared to RSA is limited. Our soon to be published clinical study comparing migrations of tibial implants up to 2 years, shows that RSA and CT-RSA shown deviating migration curves. It is therefore necessary to determine which method is the most accurate. This study aims to compare the accuracy of CT-RSA and traditional RSA for translations, rotations, and maximum total point motion (MTPM) in a tibial implant in a porcine phantom knee. To evaluate MTPM, we will validate a novel MTPM-software designed to evaluate MTPM, representing the first attempt to integrate such a tool into an accuracy study.

Methods
Using a porcine tibia phantom in a micrometer platform, we created a controlled test bed for comparing CT-RSA and RSA, both marker-based and model-based RSA. CT-RSA and RSA were used to assess varying x-y-z translations and rotations, and MTPM. Measurements were conducted under varying known displacements and rotations applied using a micrometer (25 m-PT3/M X, Y, Z travel Translational Stage and PRO1A/M Precision Rotation Platform, Thorlabs, Inc. Newton, NJ). We performed 11 translations per Degree-of-Freedom (DOF), 7 rotations per DOF and 7 MTPM´s, which totals to 61 measurements for accuracy. Furthermore, for the CT scans we conducted with multiple radiation dose protocols and iterations. Novel software (Sectra AB, Sweden) was employed to quantify MTPM, promising increased automation and analytical precision. Accuracy was evaluated by comparing measured values from each modality against the known displacements. Bland-Altman plots will be used to quantify differences between the methods.

Results
While definitive results are pending, the expected outcomes include a detailed understanding of the accuracy of CT-RSA relative to traditional RSA. We aim to get closer to the important question of the validity of CT-RSA as well as be the first to validate MTPM for any RSA-method. Preliminary observations suggest that CT-RSA could offer comparable accuracy in translations and rotations.

Conclusion
This study pioneers the application of a novel MTPM evaluation software in CT-RSA accuracy studies, marking a step forward in orthopedic research methodologies. By benchmarking CT-RSA against the established RSA standard, we aim to determine its viability as a reliable alternative. The outcomes of this study could have substantial implications for preclinical testing, implant development, and long-term clinical monitoring.

References

1. Engseth LHW, Schulz A, Pripp AH, Röhrl SMH, Øhrn FD. CT-based migration analysis is more precise than radiostereometric analysis for tibial implants: a phantom study on a porcine cadaver. Acta Orthop. 2023;94:207-14.
2. Øhrn FD, Engseth LHW, Pripp AH, Röhrl SMH, Schulz A. Dose reduction does not impact the precision of CT-based RSA in tibial implants: a diagnostic accuracy study on precision in a porcine cadaver. Acta Orthop. 2023;94:550-44.
3. Brodén C, Giles JW, Popat R, Fetherston S, Olivecrona H, Sandberg O, et al. Accuracy and precision of a CT method for assessing migration in shoulder arthroplasty: an experimental study. Acta Radiol. 2020;61(6):776-82.
4. Brodén C, Sandberg O, Olivecrona H, Emery R, Sköldenberg O. Precision of CT-based micromotion analysis is comparable to radiostereometry for early migration measurements in cemented acetabular cups. Acta Orthop. 2021;92(4):419-23.
5. Brodén C, Sandberg O, Sköldenberg O, Stigbrand H, Hänni M, Giles JW, et al. Low-dose CT-based implant motion analysis is a precise tool for early migration measurements of hip cups: a clinical study of 24 patients. Acta Orthop. 2020;91(3):260-5.

The accuracy and precision of CT-RSA in joint arthroplasty: a systematic literature review

Sjors F. van de Vusse ^* BSc, Nienke N. de Laat * MSc, MD, Lennard A. Koster * MSc, Bart L. Kaptein * MSc, PhD.

^Leiden University, Leiden University Medical Center, Albinusdreef 2, 2333 ZA Leiden, The Netherlands.
*Department of Orthopaedics, Leiden University Medical Center, Albinusdreef 2, P.O. Box 9600, 2300 RC Leiden, The Netherlands.

Abstract

Purpose: Computed tomography-based radiostereometric analysis (CT-RSA) is an alternative to conventional radiostereometric analysis (RSA), circumventing the need for operative insertion of tantalum markers. The reported accuracy of RSA in measuring implant migration is between 0.05-0.50 mm for translations and 0.15-1.15 degrees for rotations. However, the accuracy and precision of different CT-RSA techniques and joints is still unclear, and the effective radiation dose (ED) of CT-RSA is usually higher than RSA. In this systematic literature review, we aimed to provide an overview of the accuracy, precision, clinical precision, and ED of CT-RSA techniques.

Methods: We performed a systematic search in Pubmed, Cochrane, and Embase databases. Eligible studies were screened and reviewed by two authors independently. Risk of bias was assessed using the Critical Appraisal Skills Programme tool. Main outcomes were accuracy, precision, and clinical precision of CT-RSA in 6 degrees of freedom. Secondary outcome was the mean ED.

Results: Twenty-three studies were included involving 163 patients, 20 human cadaveric, 3 porcine cadaveric, and 7 synthetic models. Six different CT-RSA techniques were used to study in total 6 different joint components in cervical disc replacement and shoulder, hip, and knee arthroplasty. CT-RSA accuracy ranged between 0.02-0.61 mm and 0.03-0.71

degrees. CT-RSA precision ranged between 0.01-0.47 mm and 0.00-1.09 degrees. CT-RSA clinical precision ranged between 0.03-1.36 mm and 0.06-2.25 degrees. The mean ED of CT-RSA ranged between 0.02-5.80 mSv.

Conclusion: CT-RSA shows comparable accuracy and precision to standard RSA. Therefore, CT-RSA is a promising suitable alternative to RSA, despite its higher radiation dose.

Migration in total hip arthroplasty with the Global Tissue Sparing (GTS) stem compared with uncemented HA coated Taperloc stem: a radiostereometric study with 5 years of follow-up

J.H. Pasma[1], I.F. Blom[1,2], N. de Esch[1], S.B. Keizer[3], S.B.W. Vehmeijer[1], N.M.C. Mathijssen[1]

[1]Reinier Haga Orthopedisch Centrum, Zoetermeer, the Netherlands

[2]Department of Radiology, Delft, the Netherlands

[3]Department of Orthopaedic Surgery, Haaglanden Medical Center, the Hague, the Netherlands

Purpose

Uncemented total hip arthroplasty (THA) have shown excellent rates of bone ingrowth, longevity and clinical results. However, wear and migration could result in osteolysis and loosening, respectively. After failure of a primary THA, a more challenging and costly hip revision surgery is needed, mainly due to management of the bone stock loss. Therefore, the new shorter Global Tissue Sparing (GTS) stem (Zimmer Biomet, Warsaw, IN) was developed to prevent the loss of bone stock. In this study, we compared the migration and evaluated the clinical of the GTS stem to the Taperloc stem (Zimmer Biomet, Warsaw, IN), during 5 years follow-up.

Methods

In this prospective randomized controlled trial, 51 primary uncemented THAs were implanted, of which 25 GTS stems and 26 Taperloc stems, both combined with the uncemented Regenerex Ringloc+ cup with a E1-poly liner (Zimmer Biomet, Warsaw, IN). RSA radiographs were obtained in supine position direct postoperatively, at 6 weeks, 3 months, 6 months, 1, 2 and 5 years postoperatively. Migration of the stem was calculated using model-based radiostereometric analysis (mRSA) in terms of translations and rotations. Double examination was performed at 2 years follow-up to calculate the precision. To evaluate the clinical results, PROMs (HHS, HOOS, EQ-5D) were registered. Linear mixed models were used to test whether there is a significant difference between the migration of the cups and over time.

Results

The GTS stem shows a comparable migration to the Taperloc stem during 5 years follow-up. Both stems showed a statistically significant translation along the y- and z-axes over time ($p<0.035$) and stabilized 1 year after surgery. However, only the translation along the y-axis was higher than the precision interval at 5 years follow-up (GTS: -1.10 (1.26) mm; Taperloc: -1.23 (1.51) mm), indicating a real migration. Both stems did not show a statistically significant rotation over time and the rotations did not reach the precision interval. All PROMs improved after surgery and remained stable during 5 years follow-up.

Conclusion

The migration at 5-years follow-up is comparable between the GTS stem and the Taperloc stem. This indicates that the short GTS stem is a good alternative to the currently used Taperloc stem. However, long-term results are needed to show whether there is also no difference in revision rate.

Precision of an automated volume-based CT radio-stereometric analysis in a porcine cadaver

We would like to apply for the Edward Valstar Award and Lars Weidenhielm Award

M. Acke[1], B. Keelson[1], L. H. W. Engseth[6], G. Van Gompel[1,4], F-D. Øhrn[5], J. De Mey[4], A. Schulz[2,3], S. M. Röhrl[2,6], N. Buls[1,4]

[1] *Faculty of Medicine, Vrije Universiteit Brussel, Brussels, Belgium*

[2] *Faculty of Medicine, University of Oslo, Oslo, Norway*

[3] *Radiology, Oslo University Hospital, Oslo, Norway*

[4] *Radiology / Medical Physics, UZBrussel, Brussels, Belgium*

[5] *Department of Orthopaedics, Kristiansund Hospital, Norway*

[6] *Division for orthopaedic surgery, Oslo University Hospital, Oslo, Norway*

Purpose

The gold standard for implant migration analysis, radiostereometric analysis (RSA), can be time consuming and resource intensive. CT-based RSA (CT-RSA) offers a promising, non-invasive alternative. However, most CT-RSA solutions currently available still require several manual steps and user expertise. We introduce a new, automatic, model-based CT-RSA method for possibly quantifying implant migration. The purpose of this study is to compare the performance of an automated volume-based CT-RSA and a stepwise landmark-based CT-RSA method with existing marker-based RSA (UmRSA, RSA Biomedical, Umeå, Sweden) using a preclinical porcine model.

Methods

Data from a previous cadaveric study were reused [1]. A tibial implant (Zimmer Biomet NexGen CR) and tantalum markers had been placed in a porcine knee. Biplanar radiographs and CT scans were acquired for 7 different random positions, resulting in 21 double examinations. Three methods were compared in quantifying the accuracy of zero motion: the gold standard marker-based radiostereometric analysis (RSA), a stepwise landmark-based CT-RSA, and a new automated volume-based CT-RSA. The CT-RSA software uses SimpleITK and Pyvista. A full description of the software model was published previously [2]. In brief, two leg positions were compared by segmenting the tibia and tibial implant using thresholding, morphological operations, and component analysis. Rigid pair-wise image registration aligns the two images by applying transformations (T_{tibia} and $T_{implant}$) to the tibia and implant segmentations. If no implant migration occurs, aligning the tibia also aligns the implant. Otherwise, relative motion between the separate alignments can detect implant migration using the following formula:

$$T_{relative} = T_{implant} \times T_{tibia}^{-1}$$

Both CT-RSA methods calculate a Total Translation (TT) metric, representing maximum implant migration, similar to maximum total point motion (MTPM) in RSA. Beyond the automation difference, stepwise landmark-based and automated volume-based CT-RSA differ in calculating Total Translation (TT) and representing maximum migration direction. The stepwise landmark-based CT-RSA uses a handful of virtual operator-

placed landmarks, while volume-based CT-RSA evaluates TT automatically across all implant surface voxels. In addition, the volume-based CT-RSA method automatically visualises the maximum migration direction as a vector on a 3D mesh.

The precision of the methods was assessed by comparing the MTPM of RSA and the TT of both the CT-RSA methods using a two-sample t-test. Results are presented with mean values and their 95% confidence interval. Assuming zero motion, a higher measured motion indicates a lower precision of the method.

Results

The mean precision of marker-based RSA was 0.45 mm (95%CI: 0.19–0.70 mm) [1]. Stepwise landmark-based CT-RSA showed a significantly higher precision than RSA ($p<0.001$), with a precision of 0.15 mm (95%CI: 0.12–0.18 mm). The novel automated volume-based CT-RSA had a similar precision of 0.16 mm (95%CI: 0.13–0.19 mm).

Conclusion

Compared to conventional RSA, our novel, automated, volume-based CT-RSA method offers improved precision in evaluating tibial implant migration in a porcine cadaver. This method shows similar precision as earlier published CT-RSA software [1]. Volume-based CT-RSA automatically captures the full motion of all implant surface points without user intervention, while stepwise landmark-based CT-RSA tracks only the most displaced landmark.

[1] **Engseth LH, Schulz A, Pripp AH, et. al.** CT-based migration analysis is more precise than radiostereometric analysis for tibial implants: a phantom study on a porcine cadaver. Acta Orthop. 2023; 94: 207-14. doi: 10.2340/17453674.2023.12306.

[2] **Keelson B, Buzzatti L, Cerankaet J, et. al.** Automated motion analysis of bony joint structures from dynamic computer tomography images: a multi-atlas approach. Diagnostics. 2021; 11(11): 12062. doi: 10.3390/diagnostics11112062.

Multi-center RSA study of a novel cementless total knee replacement

Douglas D.R. Naudie, Brent Lanting, Eric R. Bohm, Matthew G. Teeter,
Thomas R. Turgeon, Trevor C. Gascoyne

Introduction:
The purpose of this study is to determine the risk of aseptic loosening of a novel cementless total knee arthroplasty (TKA) based on micromotion analysis using radiostereometric analysis (RSA).

Methods:
Thirty patients requiring primary TKA were enrolled at two academic joint replacement centres. All patients received a porous CONCELOC tibial baseplate paired with a cruciate-retaining LEGION porous (n=24) or LEGION cemented (n=6) femoral component (Smith & Nephew, Memphis, TN). The patella was selectively resurfaced based on surgeon preference and was resurfaced using either a cementless CONCELOC (n=10) or a cemented GENESIS inset biconvex patella (n=6). During surgery, RSA beads were inserted into the proximal tibia, distal femur, and the patella when the cementless implant was used.

Patients received supine and lateral RSA imaging at six weeks (baseline), and six, 12, and 24 months following surgery. The primary study outcome was change in maximum total point motion (MTPM) of the tibial baseplate. Secondary study outcomes included subsidence and total translation (vector sum) migration of the tibial baseplate, femoral component, and cementless patella. Patient reported outcome measures (PROMs) from pre-operative to post-operative time points using Oxford-12 Knee Score (OKS), European Quality of Life (EQ-5D), Forgotten Joint Score (FJS), and visual analogue scale for satisfaction with surgery (Sat VAS) were also collected.

Results:
Our patient cohort had a mean age at surgery of 66 years (range: 53-79) and a mean body mass index of 30.6 kg/m^2 (standard deviation [SD]: 3.8). Mean tibial baseplate MTPM at six, 12, and 24 months was 1.21mm (SD: 0.97), 1.03mm (SD: 0.47), and 1.08mm (SD: 0.49), respectively. Subsidence and total translation of the baseplate remained constant from six months to 24 months, indicating stable fixation. Sufficient femoral RSA beads were visible in 15 patients. Mean MTPM of the femoral component at six, 12, and 24 months was 1.12 (SD: 0.84), 0.99 (SD: 0.70), and 1.03 (SD: 0.58). Subsidence and total translation of the femoral component remained constant from six months to 24 months, indicating stable fixation. Sufficient patellar RSA beads were visible in 9 patients who received the cementless implant. Mean MTPM of the patellar component at six, 12, and 24 months was 0.95 (SD: 0.48), 0.96 (SD: 0.35), and 1.20 (SD: 0.58).

Patients reported substantial improvement in functional (OKS, FJS) and health-related (EQ-5D) PROMs following surgery. Patients reported 83.8%, 85.0%, and 90% satisfaction VAS at six, 12, and 24 months, respectively.

Conclusion:
This study provides valuable early data on the fixation of this novel cementless TKA implant. Implant migration patterns for this patient cohort did not indicate any concerns for future aseptic loosening.

Tibial Baseplate Orientation Which Minimizes Registration Error in Model-Based RSA is Not Aligned with the Anatomical Coordinate System

Rubiana Monteiro (KinAlign Orthopaedics, Sacramento CA) and M. L. Hull (University of California at Davis, Davis CA)

Background: Accuracy of model-based radiostereometric analysis (MBRSA) in calculating tibial baseplate migration depends on baseplate shape and orientation relative to the imaging planes. To quantify accuracy, two error terms must be determined and include trueness (i.e. systematic error or bias) and precision (i.e. random error or repeatability). Minimizing the bias error is particularly important in MBRSA where maximum total point motion (MTPM) is the dependent variable of interest since the threshold for assessing baseplate stability at the group level is 0.5 mm. In general, for a specified baseplate shape, the orientation which exhibits the greatest variation in geometry in the image silhouette hence minimizing bias in registration may not be aligned with the anatomical coordinate system. For a new cementless tibial baseplate, the primary objective was to determine the optimal orientation which minimizes the bias error in MTPM.

Methods: A tibia phantom was oriented to achieve 24 different combinations of flexion and valgus angles with three pairs of radiographs acquired for each combination. Flexion was varied from 0° to 25° and valgus was varied from 0° to 15° each in 5° increments. Radiographs were processed in MBRSA software and the mean MTPM for each flexion/valgus angle combination was determined for both CAD and reverse-engineered (RE) models. Mean MTPM indicated bias error during model registration because no migration of the tibial baseplate occurred.

Results: Mean MTPM was strongly influenced by baseplate orientation. For both the CAD and RE models, mean MTPM decreased by 3-fold between the anatomical orientation (i.e. flexion/valgus = 0°/0°) and the optimal orientation which occurred for a flexion/valgus angle combination of 15°/0°). However, mean MPTM was sensitive to flexion/valgus angle combinations close to the optimal

orientation. For flexion/valgus angle combinations of 10°/0° and 20°/0º, mean MPTM error increased by about 4-fold and 6-fold, respectively.

Conclusions: Because mean MTPM can be strongly influenced by baseplate orientation and because the corresponding relative bias error can represent a large percentage (> 40%) of the 0.5 mm threshold, the optimal orientation for a specified baseplate should be determined as a prerequisite to any MBRSA study. Since in general, the optimal orientation will not align with the anatomic coordinate system, migration results must be computed using a local coordinate system. For the baseplate herein, a flexion angle of 15º must be insured to avoid inflating the bias error in clinical use.