2017 ANZORS-RSA Joint Conference

23rd Annual ANZORS Conference in conjunction with the 5th Biennial International RSA Meeting

6th – 8th October 2017

Program

New Royal Adelaide Hospital,

Corner North Terrace/Port Road, Adelaide, SA 5000, Australia

2017 ANZORS-RSA Joint Conference
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2017 ANZORS-RSA Joint Conference

President's Welcome

It's my pleasure to welcome everyone to the 23rd annual conference of the Australian & New Zealand Orthopaedic Research Society. This year, ANZORS is privileged to hold our annual conference in collaboration with the 5th biennial International Clinical RSA Research Network Conference. This brings together the leading orthopaedic scientists from across Australia and New Zealand with international leaders in orthopaedic surgery and orthopaedic surgery outcomes. For those of you have travelled from interstate or overseas, welcome to Adelaide. I hope you enjoy your time in the city I now call home.

This conference is the product of months of tireless work by our local hosts Dr Stuart Callary, Professor Bogdan Solomon and Professor Gerald Atkins, with the support of Dr Egon Perilli and Associate Professor Nathan Pavlos. The quality of the program is exceptionally impressive, especially when one considers that the hospital in which we meet only opened one month before the date of the conference. The challenges faced by organisers should really be put into context by the time constraints they have had to work with. On the topic of the venue (the New Royal Adelaide Hospital), I cannot go without expressing my gratitude to the South Australian Government and contractors who were able to finish the most expensive hospital ever built in Australia ($2.5-$3bn) just in time for our conference. This was rather considerate of them!

This year's conference is supported by companies from the medical device, orthopaedic and health care industries, with support from two of the universities in Adelaide. The generosity shown by our sponsors allows the host organisations to offer significant travel support to junior members of the two societies. I am a strong believer that societies, such as ANZORS, have a responsibility to ensure that the engines of the research machine – the PhD students and ECRs – have an opportunity to present their work in a safe, but challenging, academic environment. Our ability to help share some of the financial burden of this is only a small cost in comparison to the long term benefit the opportunity for networking and dissemination will offer our emerging scientists.

This conference has been strategically timed to precede the Australian Orthopaedic Association (AOA) ASM. An effective interaction between orthopaedic scientists and clinicians is essential for impactful research translation. This is more important than ever as we find ourselves in an exceptionally competitive funding environment. I hope to continue a stronger association with the AOA in to the future.

Please enjoy the conference, take time to speak to people you've not met before, and explore topics that may seem peripheral to your work.

Dominic Thewlis
President, Australian & New Zealand Orthopaedic Research Society
NHMRC R.D Wright Fellow and Associate Professor
The University of Adelaide

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Trabecular Metal™ cups used in revision THA have shown to be 21% LESS LIKELY to be re-revised **due to infection.**[1,2]

(statistically significant, p-value=0.036)

- **Trabecular Metal**™ cups used in revision THA have shown to be **21% less likely** to be re-revised due to infection (statistically significant, p-value=0.036).[1, 2]
- For high risk patients (1st revision indication being infection) **Trabecular Metal** cups appear to be **35% less likely** to be re-revised for infection. However, this has not reached statistical significance due to limited sample size (not statistically significant, p-value=0.108).[3]
- **Trabecular Metal** cups used in revision THA have shown to be **11% less likely** to be re-revised for any reason (statistically significant, p-value=0.015).[1]

References

1. According to the UK National Joint Registry data from 2003 to 2015 where 9,573 Trabecular Metal and 30,452 non-Trabecular Metal cups were used in revision THA and based on hazard ratios adjusted by patient gender, age group, and indications (OA/non-OA).
2. UK National Joint Registry data shows a higher percentage of TM cups were used with antibiotic bone cement compared to all other non-TM cementless cups.
3. According to the UK National Joint Registry data from 2003 to 2015 where 628 Trabecular Metal and 2,114 non-Trabecular Metal cups were used in revision THA and based on hazard ratios adjusted by patient gender, age group, and indications (OA/non-OA).

This material is intended for health care professionals. Distribution to any other recipient is prohibited.

For product information, including indications, contraindications, warnings, precautions, potential adverse effects and patient counseling information, see the package insert and www.zimmerbiomet.com.

The statements have not been evaluated by the FDA for the Zimmer Biomet Trabecular Metal Cups and do not alter the cleared indications for use.

Check for country product clearances and reference product specific instructions for use. Not for distribution in France.

The complete UK National Joint Registry report can be found at: **www.zimmerbiomet.com/TM**

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MEDICAL DEVICE RESEARCH INSTITUTE

The Medical Device Research Institute (MDRI) at Flinders University is a multi-disciplinary Institute with the expertise and capabilities to deliver innovative solutions to the medical and allied health sectors. The MDRI is head-quartered within Flinders University's state-of-the-art $120 million building at the new Tonsley precinct.

Our vision is to be the Australian leader in medical device research and development.

Primarily focussed in the areas of assistive technology and rehabilitation engineering; biomechanics and implants; computational biomechanics; devices, sensors and signals; digital health; medical image analysis and medical simulation, it brings a collaborative approach to the development of high-technology devices.

The MDRI is home to the award-winning Medical Device Partnering Program (MDPP), a unique industry engagement program which fosters collaboration between inventors, researchers, industry and end-users in the development of cutting-edge medical devices and assistive technologies.

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www.flinders.edu.au/mdri

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Australian New Zealand Orthopaedic Research Society (ANZORS) Committee Members

President A/Prof Dominic Thewlis	NHMRC R.D. Wright Fellow and Associate Professor, Centre for Orthopaedic & Trauma Research, The University of Adelaide
Secretary Dr Egon Perilli	Senior Lecturer in Bioengineering, The Medical Device Research Institute, College of Science and Engineering, Flinders University, Adelaide
Treasurer A/Prof Nathan Pavlos	Head of the Cellular Orthopaedics Laboratory, Centre for Orthopaedic Research, School of Surgery, University of Western Australia.
Immediate Past President W/Prof Jiake Xu	Head of Molecular Laboratory, School of Pathology and Laboratory Medicine, University of Western Australia

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Roentgen Stereophotogrammetry Analysis (RSA) Committee Members

President Prof Rob Nelissen	Chairman, Department of Orthopaedics, Leiden University, Netherlands
Vice President Prof Johan Kärrholm	Chief Physician, Department of Orthopaedics , Institute of Clinical Sciences, Sahlgrenska Academy at University of Gothenburg, Sweden
Secretary A/Prof Maiken Stilling	Department of Clinical Medicine, Aarhus University, Denmark
Treasurer Prof Mike Dunbar	Director, Orthopaedic Research, Dalhousie University, Halifax, Novia Scotia, Canada
Editor Dr Bart Kaptein	Department of Orthopaedics, Leiden University Medical Center, Netherlands

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ANZORS Organising Committee

A/Prof Dominic Thewlis

Dr Egon Perilli

A/Prof Nathan Pavlos

Prof Gerald Atkins

Prof Bogdan Solomon

RSA Organising Committee

Dr Stuart Callary

Prof Bogdan Solomon

A/Prof David Campbell

Prof Donald Howie

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ANZORS-RSA Scientific Committee

(alphabetical surname order)

Dr David Ackland
Dr John Arnold
Prof Gerald Atkins
Dr Stuart Callary
A/Prof John Costi
Dr Tania Crotti
A/Prof Colin Dunstan
Dr Justin Fernandez
Prof David Findlay
Dr Claire Jones
A/Prof Pazit Levinger
Dr ZuFu Lu
Dr Saulo Martelli
Dr David Musson
A/Prof Nathan Pavlos
Dr Egon Perilli
Prof Peter Pivonka
Mr Bryant Roberts
Dr Melissa Ryan
Prof Bogdan Solomon
Dr Corey Scholes
A/Prof Dominic Thewlis
Prof Cory Xian
W/Prof Jiake Xu

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Travel Grant Recipients

ANZORS-RSA are proud to support their early career researchers. This year we have awarded 27 travel grants. This represents a significant reinvestment of our funds to support the dissemination of quality orthopaedic research.

First Name	Surname	Institution
ANZORS		
Long	Bai	Queensland University of Technology, Australia
Martina	Barzan	Griffith University, Australia
Joseph	Cadman	Macquarie University, Australia
Claudia	Di Bella	University of Melbourne, Australia
Quyen	Do	University of New South Wales, Canberra, Australia
Zhibin	Du	Queensland University of Technology, Australia
Anthony	FitzPatrick	University of Canterbury, Christchurch, New Zealand
Nicola	Hribar	University of Canberra, Australia
Vahidreza	Jafari Harandi	The University of Melbourne, Australia
Jacob	Kenny	University of Western Australia, Australia
Sophia	Leung	University of Auckland, New Zealand
David	Musson	University of Auckland, New Zealand
Kwong Ming	Tse	University of Melbourne, Australia
Silvia	Trichilo	The University of Melbourne, Australia
Luisa	Schreck	University of New South Wales, Australia
Chelsea	Woo	University of New South Wales, Australia
RSA		
Lene	Dremstrup	University Clinic for Hand, Hip and Knee Surgery, Holstebro, Denmark
Lars	Hansen	Orthopedic Research Unit, Aarhus University Hospital, Denmark
Chalotte	Hemmingsen	Orthopedic Research Unit, Aarhus University Hospital, Denmark
Peter Bo	Jørgensen	Aarhus University Hospital, Denmark
Daan Karina	Koppens	Regional Hospital of Holstebro, Denmark
Nørgaard	Linde	Aarhus University Hospital, Aarhus, Denmark
Joris E.	Meinardi	Leiden University Medical Center, Dep. of Orhopedics, Netherlands
Bart	ten Brinke	Amphia Ziekenhuis Breda, Netherlands
Janni	Thillemann	University Clinic for Hand, Hip and Knee Surgery, Holstebro, Denmark
Emil	Toft Nielsen	Aarhus University Hospital, Denmark
Koen	van Hamersveld	Leiden University Medical Center, Netherlands

2017 ANZORS-RSA Joint Conference

Keynote Speaker

Prof. Stuart B. Goodman MD MSc PhD FRCSC FACS FBSE FICORS

Stuart B. Goodman is the Robert L. and Mary Ellenburg Professor of Surgery, and Professor with Tenure in the Department of Orthopaedic Surgery at Stanford University. He has a courtesy appointment in the Department of Bioengineering, and is a Fellow of the Institute of Chemistry, Engineering and Medicine for Human Health (ChEM-H) at Stanford University. He was Chief of Orthopaedic Surgery at Stanford University from 1994-2002.

Dr. Goodman received his BSc, MD and MSc (Institute of Medical Science) from the University of Toronto, and his PhD in Orthopedic Medical Science from Lund University in Sweden. He is a Fellow of the Royal College of Surgeons (Canada), the American Academy of Orthopaedic Surgeons and the American College of Surgeons.

Dr. Goodman's clinical practice concentrates on adult reconstructive surgery. His clinical research interests center on the outcome of surgery for arthritis including primary and revision total joint replacement, juvenile arthritis, and osteonecrosis of the hip and knee. His basic science interests center on biocompatibility of orthopaedic implants, inflammation, and musculoskeletal tissue regeneration and repair. Dr. Goodman is a member of numerous academic organizations including former Chairman of the AAOS Biological Implants Committee, and a former member of the AAOS Biomedical Engineering Committee. He is a member of the Hip Society, Knee Society and AAHKS, a consultant to the Orthopaedic and Rehabilitation Devices Advisory Panel of the FDA, and former vice-chairman of the Musculoskeletal Tissue Engineering study section at NIH.

Dr. Goodman is on the editorial board of the Journal of Orthopaedic Research (Associate Editor), Clinical Orthopaedics (Deputy Editor-Hip Society Liason), Biomaterials (Associate Editor), Journal of Arthroplasty, Journal of Biomedical Materials Research, and other journals, and is a manuscript reviewer for over 20 journals in the fields of orthopaedic surgery, arthritis, bioengineering and biomaterials. Dr. Goodman has published over 450 peer-reviewed manuscripts in medical and bioengineering journals. Dr. Goodman and co-workers have received awards for their research from the Society for Biomaterials, Orthopaedic Research Society, the American Orthopaedic Association, Western Orthopaedic Association, and the Association of Bone and Joint Surgeons.

Dr. Goodman was awarded the Clemson Award for Basic Research from the Society For Biomaterials in May 2000. He was the President of the Society For Biomaterials (2001-2) and served on the Board of Directors of the Orthopaedic Research Society. Dr. Goodman served as Co-Chair for the 1995, 2000 and 2007 NIH/AAOS-sponsored workshops on Implant Wear. Dr. Goodman was recognized as a Fellow, Biomaterials Science and Engineering (FBSE) by the International Union of Societies, Biomaterials Science and Engineering in May 2004, a Fellow of the Japanese Society of the Promotion of Science in 2011, a Fellow of the American Institute of Medical and Biological Engineers in 2012 and a Fellow of the International Combined Orthopaedic Research Societies in 2016.

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Keynote Speaker

Prof. Maiken Stilling

Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
Department of Orthopedics, Aarhus University Hospital, Aarhus, Denmark
Department of Orthopedics, University Clinic of Hand, Hip, and Knee Surgery, Holstebro, Denmark

Maiken Stilling is Associate Professor at Aarhus University and Hand Surgeon in the Department of Orthopaedics at Aarhus University Hospital, Denmark. She pursued her academic career in RSA Research in 2004 with Professor Kjeld Søballe and defended her PhD Thesis on polyethylene wear and survival of total hip arthroplasty in 2009. As Director of RSA Research at Aarhus University Hospital in Aarhus and University Clinic of Hand, Hip, and Knee Surgery in Holstebro Maiken has initiated and completed numerous randomized studies on hip, knee and shoulder arthroplasties. Due to her clinical interest in hand surgery she applied RSA for evaluation of trapeziometacarpal arthroplasty of the thumb, which is the fulcrum in her current research activities. Maiken supervise a large skilled and diligent interdisciplinary research group of Engineering and Technology Students, Diploma Students, and PhD Students.

Maiken is part of the initiative-group for the international Clinical RSA Research Network, and she has participated in formalization of the International RSA Society as Secretary and Board Member. Further, she is on the Scientific Board of the Danish Orthopedic Society. Maiken has published 55 papers with main focus on RSA, she has chaired and taught several PhD courses in RSA methodology.

Since 2014 Maiken has been project leader and chairman of the steering committee for the technological RSA development project "AutoRSA" at Aarhus University Hospital, which mission to transform RSA from a research tool into an automated clinically integrated image-diagnostic platform.

Maiken's research interests, activities and experience further include experimental and clinical research targeting 1) optimization of patient pathways, 2) improvements in implant tribology, survival, and function of joint prostheses, 3) evaluation of bone quality including bone density, bone histology, bone remodeling, and antiresorptive pharmaceuticals, 4) assessment of rehabilitation after prosthetic surgery during patient activity (accelerometry), gait analysis (inertia measurement unit and motion capture), PROMs, registry data, and health economic calculations, and 5) application of microdialysis for measurements of tissue ischemia and concentration of pharmaceuticals in different body compartments.

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Keynote Speaker

Prof. Bernd Grimm

After graduating as a Mechanical Engineer (Dipl.-Ing.) at the Technical University of Kaiserslautern, Germany, Bernd Grimm worked at the University of Bath, U.K. in the Department of Mechanical Engineering as a DAAD (German Academic Exchange Service) scholar. During this time and under supervision of Prof. Anthony Miles, father of the renown Dall-Miles Cable system, Bernd Grimm gained his doctoral degree investigating artificial bone graft substitutes and extenders for hip and knee arthroplasty revision surgery and designed the in-vitro test technology for it. As course director for "Engineering with German" he lectured the "Applied Mechanics" curriculum.

As graduated PhD in Biomedical Engineering, Dr. Grimm set up the orthopaedic research foundation "AHORSE" at the Atrium, now Zuyderland Medical Center and the largest hospital in the Netherlands working as Research Director together with Prof. Ide Heyligers. During this time Dr. Grimm has developed, as a pioneer in the field wearable sensor applications for the measurement of human movement and physical activity with a focus on the clinical assessment of hip and knee arthroplasty. These methods are now used by various international universities, have been the basis of many PhD thesis and topic of invited lectures and symposia.

Dr. Grimm has been an active board member of the European Orthopaedic Research Society, EORS, was elected president 2014-2016 and continues to serve as immediate past-president. As co-chair he organized the EORS 2012 and CORS 2013 congresses in Amsterdam and Venice respectively.

Dr. Grimm has been Visiting Fellow at the University of Bath, and Honorary Research Fellow at the School of Clinical Science of the University of Bristol. Furthermore, Dr. Grimm serves as editorial board member on the "Journal of Musculoskeletal Research", the "Journal of Translational Orthopaedics" and as Associate Editor for Basic Science at the "EFORT Open Reviews", the main journal of the European Federation of National Associations of Orthopaedics and Traumatology". In recognition of his "excellent professional standing and high achievements in the field of orthopaedic research" Dr. Grimm has been awarded the honorary status of "Fellow of International Orthopaedic Research" (FIOR).

Bernd Grimm is also inventor on various patents and patent applications including a modular hip stem design.

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Keynote Speaker

Prof. Peter Choong, M.D.

Prof. Peter Choong is an orthopaedic surgeon who is the Director of Orthopaedics at St. Vincent's Hospital and also the Sir Hugh Devine Chair of Surgery and Head of the University of Melbourne Department of Surgery at St.Vincent's Hospital. In addition, Prof Choong is also the Chair of the Bone and Soft Tissue Tumour service at Peter MacCallum Cancer Centre. Prof. Choong is a clinical academic who is heavily involved in teaching, training and research with a major focus of his work relating to arthritis surgery and limb reconstruction. He has published prolifically (> 300 peer reviewed publications, H-index 53) and is a recipient of many peer-reviewed grants including NHMRC, ARC, and CRC. Prof. Choong was recently awarded an NHMRC CRE for outcomes research in total joint arthroplasty. Prof. Choong has held many national and international leadership positions including President of the Australian Orthopaedic Association, Chair of the Board in Orthopaedic Surgery at the RACS, and Chair of the Musculoskeletal Clinician Leadership Group at the Department of Health and Human Services, Victoria. Prof. Choong was a foundational member and Past-President of ANZORS.

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Keynote Speaker

Prof. Rob G.H.H. Nelissen, M.D. Ph.D.

Rob is currently professor and chair of the dept. Orthopaedics at the LUMC (Leiden University Medical Center). He also holds a Medical Delta professorship at the Technical University Delft. In 2011 he participated at INSEAD in the European Health Leadership Program. He is currently the president of the Netherlands Orthopaedic Association, board member of the Netherlands Arthroplasty Register (www.lroi.nl hip, knee, shoulder, elbow, ankle, wrist and hand).

Since 2015, he is president of NORE (Network Orthopaedic Registries of Europe) an EFORT network. Among his accomplishments, he was the co-founder of the Dutch Arthroplasty Register, with currently about 600.000 Hip and Knee implants etc (99% validity). He has established also an elaborate epidemiological network of orthopaedic practices in the greater Leiden-The Hague area with > 6000 prospective hip and knee arthroplasty data. The latter was the basis for prediction modelling on outcome in orthopaedics, like the KART (knee meniscal tear cohort), Paprika and RAAK cohorts (hip-knee prostheses cohorts) and at present the LOAS (Leiden Longitudinal Osteoarthritis Study) and POT(K)Cast studies (NEJM 2017). His group developed an automatic measuring method for implant bone fixation (RSA, a tool to measure 3D migration with an accuracy of up to 0.1mm and 0.1°). His research group participated in 3 EU FP-7 grants (DeSSOs, MXL, on performance and design of total joint implants). Dr. Nelissen has co-authored more than 200 peer reviewed papers, he has supervised over 35 PhD students and a numerous number of medical and technical engineering students. He participates on new implant guidelines and registries within the IMDRF network.

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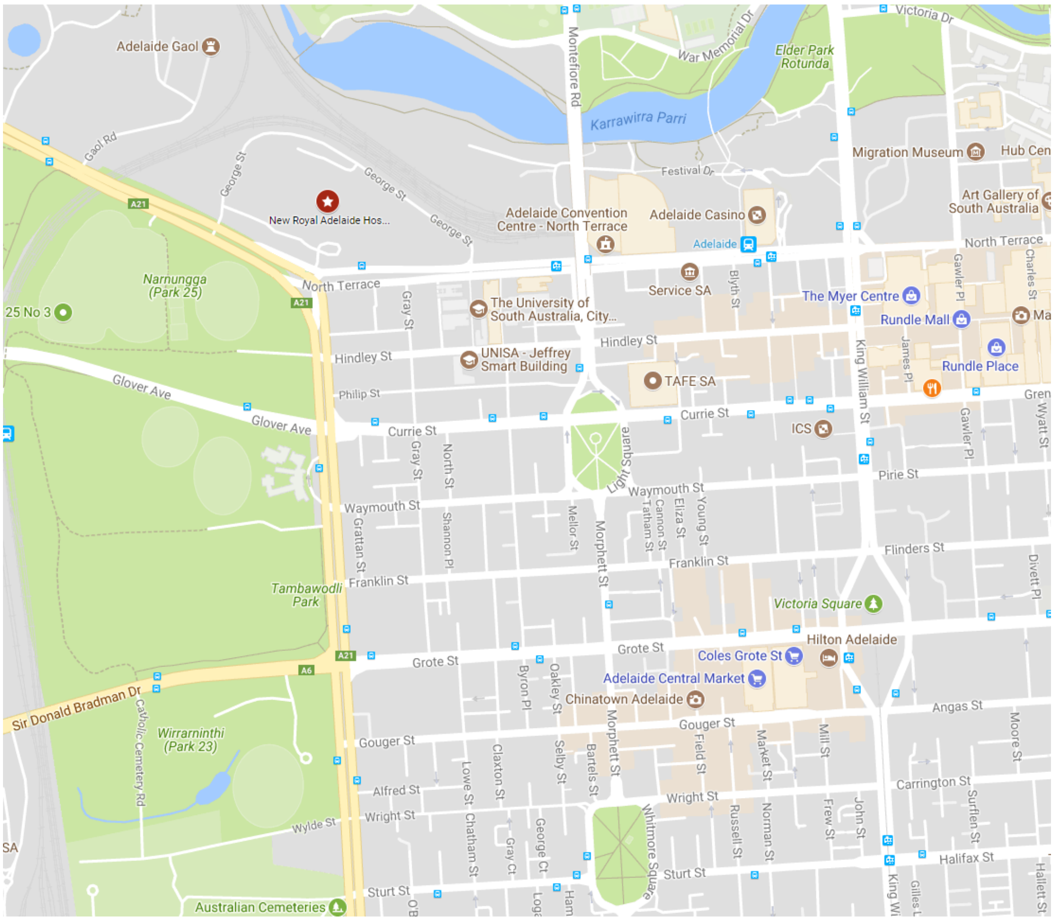
Venue

New Royal Adelaide Hospital, Level 8, Room 8D271
(From the main hospital entrance, please take the D lift, then turn left on Level 8)
Corner North Terrace & Port Road, Adelaide, SA 5000, Australia



[Google map](#)

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Day 1 (Friday October 06) – Level 8, Room 8D271
New Royal Adelaide Hospital, Corner North Tce & Port Rd, SA 5000

08:00-08:30	Coffee and registration		
08:30-08:45	**President's welcome: A/Prof Dominic Thewlis**		
08:45-09:15 **Session Sponsor: Flinders University** Session chair: Gerald Atkins	**Keynote: Prof Stuart Goodmann,** Stanford University, CA, USA **"Bone defects in the 21st century: New paradigms for the enhancement of bone healing"**		
09:15-10:25	**First name**	**Surname**	**Abstract title**
JOINT SESSION Session chairs: Egon Perilli, Gunnar Flivik	Mengzhen	Yan	Implant stiffness and peri-prosthetic changes in the rat model
	Jennifer	Hurry	Ten year migration and inducible displacement of cemented and uncemented tibial components
	Kjell G	Nilsson	Performance of highly crosslinked polyethylene cup in total hip arthroplasty
	Renee	Ormsby	The effects of vitamin E and polyethylene wear particles on osteocytes in vitro: implications for periprosthetic osteolysis
	Matthew	Tweeter	Early in vivo wear measurement of 98 total knee replacement patients using radiostereometric analysis
	Silvia	Trichilo	Image-based method to assess local changes in cortical thickness in the mouse tibia loading model, with and without administration of PTH
	Martin	Downing	Sterilisation of acetabular graft: interim radiostereometry results
	Morning coffee & tea		
10:55-12.15	**Parallel session**		
	First name	**Surname**	**Abstract title**
ANZORS Session chairs: Tania Crotti, Stuart Goodman	Esther	Camp	TWIST-1 regulated microRNA-376c is a novel player in mesenchymal stem cell growth and osteogenic differentiation
	Agnieszka	Arthur	Loss of EphrinB1 in osteoprogenitors leads to an osteoporotic phenotype in mice
	Chee Ho	Hng	Role of HOPX in BMSC proliferation and differentiation
	Zhirui	Jiang	GH insensitivity disrupts cell cycle progression in the growth plate in Mucopolysaccharidosis VII mice
	Jacob	Kenny	Identification of genes regulating osteoarthritis development using a mouse phenotype library
	Mohammadh ossein	Hassanshahi	Flavonoid genistein potentially protects bone marrow sinusoidal blood vessels and enhances their recovery following methotrexate therapy in rats
	Mohammadh ossein	Hassanshahi	Flavonoid icariin attenuates methotrexate chemotherapy-induced bone loss and bone marrow sinusoid damage in rats and stimulates migration and formation of micro-vessel like tubes in cultured sinusoidal endothelial cells
	Yu-Wen	Su	Injury site derived-neurotrophin-3 as a novel cross-talk signal induces VEGF and promotes angiogenesis and bony repair at injured growth plate
10:55-12.15	**Parallel session**		
	First name	**Surname**	**Abstract title**
RSA SESSION Session chairs: Petra Heesterbeek, David Campbell	Daan	Koppens	Equal fixation of fixed-bearing versus mobile-bearing cemented partial knee replacement. A randomised, controlled RSA study with 2-year follow-up.
	Gunnar	Petursson	Similar migration in computer assisted and conventional total knee arthroplasty: A multicenter, parallel-group, randomized controlled trial involving 54 patients
	Karina Nørgaard	Linde	Preoperative systemic bone quality does not affect tibial component migration in knee arthroplasty. A 2 year RSA study of 101 consecutive patients
	Leif	Ryd	RSA-studies on a customized metal implant for cartilage lesions in the knee
	Matthew	Teeter	Implant migration following total knee replacement using conventional or patient specific instruments
	Nils Oscar	Nivbrant	Cementless versus cemented tibial fixation in posterior stabilised total knee replacement - a randomised trial
	Petra	Heesterbeek	Determining the femorotibial contact point in 90º flexion with model-based RSA after PCL-retaining TKA: feasible, stable, and relates to clinical outcome
	Laura	Bragonzoni	Kinematic evaluation of the Zimmer PersonaTM prosthesis using dynamic RSA
	Lunch & poster viewing (poster viewing will take place between 12:15-13:00)		

13:00-13:30 Session chair: Bart Kaptein	**Keynote: Prof Maiken Stilling,** Aarhus University Hospital, Denmark **"The Development of AutoRSA including dynamic RSA and the future"**		
13:30-14:50	**First name**	**Surname**	**Abstract title**
JOINT SESSION Session chairs: David Ackland, Maiken Stilling	Lennard	Koster	Fluoroscopic analysis of two TKP systems during step-up and lunge motions
	Saulo	Martelli	In vitro real-time measurement of femoral mechanics during activity
	Lars	Hansen	Dynamic radiostereometric analysis for evaluation of hip joint pathomechanics
	Martina	Barzan	Subject-specific knee kinematics during walking in children and adolescents with recurrent patellar dislocation
	Marco	Bontempi	Kinematic comparison of pre- and post-ACL reconstruction during single-leg-squat using dynamic RSA
	Chalotte	Hemmingsen	Elbow biomechanics, radiocapitellar joint pressure, and interossous membrane strain before and after radial head arthroplasty
	Jasvir	Bahl	Changes in objectively measured activity in patients following total hip arthroplasty
	Janni	Thillemann	Dynamic radiostereometric analysis for evaluation of kinematics in the distal radioulnar joint before and after TFCC lesions
Afternoon coffee & tea and poster viewing			
15:20-16:40	**Parallel session**		
	First name	**Surname**	**Abstract title**
ANZORS Session chairs: Bernd Grimm, Nathan Pavlos	Claire	Jones	Radiographic, mechanical and histological evaluation of fusion using peek interbody cages with and without a porous titanium alloy coating, in an ovine model
	Claire	Jones	An articulated, instrumented neck for a paramedic training mannequin: proof-of-concept design and testing
	Erica	Beaucage-Gauvreau	Biomechanical investigation of a braced arm-to-thigh lifting technique for occupational tasks, with kinematic analysis and computer modeling approaches
	Jiao Jiao	Li	Osseointegrated implants in patients with peripheral vascular disease: A multi-centre case series with 1-year follow-up
	Anthony	FitzPatrick	Assessment of hip implant condition through a combined approach of acoustic emission monitoring and patient gait analysis
	David	Kitchen	Time dependent loss of trabecular bone prior to fixation in the fractured tibial plateau
	Christian M	Langton	A passive ultrasound phase-interference compensator to facilitate imaging of soft-tissues through bone
15:20-16:40	**Parallel session**		
	First name	**Surname**	**Abstract title**
RSA Session chairs: Stuart Callary, Kjell Nilsson	Xunhua	Yuan	Radiostereometric analysis using clinical radiographic views
	Martin	Downing	Migration assessment using clinical radiography and a single RSA exam
	Peter Bo	Jørgensen	Equivalent femoral stem fixation with hi-fatigue and palacos bone-cements. A 2 year randomized controlled trial with radiostereometric analysis
	Sverrir	Kiernan	Migration pattern of an anatomical stem. One year followup with RSA
	Nils Oscar	Vibrant	Prospective clinical trial assessing: the Nanos® short femoral stem prosthesis in total hip arthroplasty
	Erik	Weber	Migration pattern of a short uncemented hip stem with or without collar
	Matthew	Teeter	Change in acetabular cup orientation from supine to standing position and its effect on wear of highly crosslinked polyethylene
	David	Campbell	Wear of a second-generation XLPE liner remains low at 10 years: an RSA study
18:00-	**Young Investigators Pub-dinner** **Strictly Masters/PhD students only; free meal; must have indicated attendance during registration At Bank Street Social (v/gf available), 48 Hindley St, Adelaide; 10 min walk from Conference Venue Map: googlemap**	**RSA Group Drinks and Informal Dinner** **(not included in conference, no booking necessary, Location To Be Confirmed)**	

Day 2 (Saturday October 07) – Level 8, Room 8D271
New Royal Adelaide Hospital, Corner North Tce & Port Rd, SA 5000

07:45-08:00	Coffee & tea		
08:00-08:36	**First name**	**Surname**	**Abstract title**
David Findlay ECR Award Final Session chairs: Rami Al-Dirini, David Findlay	Dale	Robinson	Classification of fracture risk based on finite element modelling and clinical pQCT imaging of the tibia
	Claudia	Di Bella	In situ bioscaffold 3D printing for cartilage regeneration in a large animal model. Pilot study.
	Melissa	Ryan	Quantification of peri-implant bone strain during screw tightening using digital volume correlation
08:36-09:06 **Session Sponsor: The University of Adelaide** Session chair: Bogdan Solomon	**Keynote: Prof Bernd Grimm,** Zuyderland Medical Center, Heerlen, Netherlands **"Physical activity: Clinical outcome parameter, diagnostic bio-marker or medicine. Possibilities for wearable sensors in orthopaedics"**		
	Morning coffee & tea		
09:36-10:24	**First name**	**Surname**	**Abstract title**
ANZORS PhD Award Final Session chairs: Jiake Xu, Stuart Goodman	Ryan	Quarrington	Quantitative evaluation of facet deflection, strain and failure load during simulated cervical spine trauma
	Yolandi	Starczak	Vitamin D activity directly regulates osteoclastogenesis and resorptive activity
	Bryant	Roberts	Proximal tibia subchondral bone microarchitecture in varus- and valgus-aligned osteoarthritic knees: comparisons with controls
	Jasvir	Bahl	Prediction of the hip joint centre for musculoskeletal models using an articulated shape model of the pelvis in patients with end-stage hip osteoarthritis.
10:24-10:29	**Ed Valstar Recognition**		
10:29-11:17	**First name**	**Surname**	**Abstract title**
RSA PhD Award Final Session chairs: Johan Kärrholm, Bernd Grimm	Bart	ten Brinke	The role of Radiostereometric Analysis in the evaluation of orthopaedic implants in the upper extremity.
	John	Abrahams	The migration of acetabular components used after complex acetabular reconstructions
	Joris E.	Meinardi	RSA and Inducible Displacement for evaluation of orthopaedic implants
	Koen	Van Hamersveld	The epidemiological aspects of knee prosthetic loosening
11:17-12:20	**ANZORS AGM** **All delegates welcome (and encouraged) to attend**	**RSA Society Meeting** **All delegates welcome (and encouraged) to attend**	
12:30-17:00	**Half day Networking Event** **(bus transport provided; return back in Adelaide by 17:00)** **Pickup: at 12:30, New Royal Adelaide Hospital** Deviation Road winery, Adelaide Hills, SA		
19:00-	**Conference Dinner, includes Awards Announcements** La Boca restaurant, 150 North Terrace, Adelaide, SA **Map: googlemap**		

Day 3 (Sunday October 08) – Level 8, Room 8D271
New Royal Adelaide Hospital, Corner North Tce & Port Rd, SA 5000

08:15-08:45	Coffee & tea		
08:45-10:05	**Parallel session**		
	First name	**Surname**	**Abstract title**
ANZORS Session chairs: David Musson, Saulo Martelli	Kwong Ming	Tse	The influence of rotator cuff tears on shoulder joint contact behaviour after reverse total shoulder arthroplasty
	Richard	Thomas	Implant-tendon contact pressure in an anatomical total shoulder joint replacement
	Lachlan	Huntington	The use of fiberwire and fibertape in rotator cuff repair
	Joseph	Cadman	A novel intramedullary plating technique for reconstructing proximal humerus fractures
	Quyen	Do	Instrumented knee prosthesis with MWCNT/UHMWPE piezoresistive sensor
	Sophie	Rapagna	Quantification of bone microarchitecture damage of a press-fit femoral knee implant
	Nicola	Hribar	Deep knee flexion captured using a 2D-3D image registration process displays different arthrokinematics in older men and women
08:45-10:05	**Parallel session**		
	First name	**Surname**	**Abstract title**
RSA Session chairs: Leif Ryd, Bart Kaptein	Alexander Nilsskog	Fraser	Precision and accuracy of model-based radiostereometric analysis of the glenoid component in reversed total shoulder arthroplasty
	Bart	Kaptein	CT-based prosthesis migration measurements: a pilot study
	Jennifer	Hurry	Accuracy and precision of RSA in the low-dose EOS imager: a phantom model study
	Madeleine	Van de Kleut	Validation of radiostereometric analysis in six degrees of freedom for use with reverse total shoulder arthroplasty
	Petra	Heesterbeek	Accuracy of a cemented vs uncemented phantom study of a hinged type knee revision system with model based RSA
	Lars	Hansen	Precision of automated GPU accelerated analysis of dynamic RSA in the hip
	Han	Cao	Assessment of accuracy of radiostereometric analysis (RSA) in phantom experiments using a single robotic X-ray tube compared to conventional RSA
	Trygve	Holm-Glad	High precision and accuracy of model-based RSA in total wrist arthroplasty
10:05-10:35 **Session Sponsor: The Hospital Research Foundation** Session chair: Peter Pivonka	**Keynote: Prof Peter FM Choong,** St. Vincent's Hospital Melbourne; University of Melbourne, VIC, Australia **"Orthopaedics – A technology driven specialty"**		
	Morning coffee & tea		
11:05-12:25	**Parallel session**		
	First name	**Surname**	**Abstract title**
ANZORS Session chairs: Yin Xiao, Christian Langton	David	Musson	A novel collagen scaffold for improved tendon-bone healing
	Claudia	Di Bella	Co-axial bio-printing of stem cells for the regeneration of articular cartilage
	Ryan	Gao	Human spinal bone dust as a potential local autograft: in vitro potent anabolic effect on human osteoblasts
	Sophia	Leung	Combination loading produces a chondrogenic phenotype than uniaxial loading
	Long	Bai	The influence of Si-doped titania nanotube arrays on endothelial cell functionality
	Dale	Robinson	Design of a novel joint replacement for the human temporomandibular joint
	Erica	Beaucage-Gauvreau	Validation of full body opensim model with detailed lumbar spine to evaluate biomechanics of lifting tasks
	Jorge Enrique	Garcia	How the Therapeutic Goods Administration (TGA) uses Implant Registry Data
11:05-12:25	**Parallel session**		

	First name	Surname	Abstract title
RSA SESSION Session chairs: Stephan Röhrl, Bo Nivbrant	Bart	Kaptein	Unexpected migration between the head and stem in modular neck hip implants
	Stuart	Callary	The wear rate of highly cross-linked polyethylene is not increased by large articulations: mid term follow-up of a randomised controlled trial
	Andreas	Burger	Clinical wear results for a vitamin-E stabilized polyethylene acetabular liner using a novel model-based approach for measuring wear in radio-opaque cups
	Lene	Dremstrup	Similar press-fit fixation with a spherical and a conical cup design in the trapeziometacarpal joint. A radiostereometric analysis in a pig model.
	Maiken	Stilling	Good 2 year results with a new conical press-fit cup design and dual-mobility articulation in total trapeziometacarpal arthroplasty
	Martin	Downing	Inducible micromotion and contact point provide insight into the migration of pegged glenoid implants
	Emil	Toft Nielsen	Influence of anterolateral ligament on knee laxity during flexion-internal rotation. A biomechanical cadaver study using dynamic radiostereometric analysis.
	John	Field	The utilization of radiostereometric analysis in animal models of human orthopaedic disease
Lunch & poster viewing (poster viewing will take place between 12:40-13:10)			
13:10-13:40 Session chair: Donald Howie	**Keynote: Prof Rob Nelissen,** Leiden University Medical Centre; TU Delft, Netherlands **"The value of RSA and Registries for patient safety"**		
13:40-15:00	**First name**	**Surname**	**Abstract title**
JOINT SESSION Session chairs: Rob Nelissen, Peter Choong	Donald	Howie	Implant-related revision of primary total hip replacement at 10 year follow-up of a randomised trial of articulation size
	Per-Erik	Johanson	Early proximal migration of cemented cups and the occurrence of aseptic loosening
	Darcy	Noll	The diagnostic performance of acetabular migration to detect aseptic loosening after primary total hip arthroplasty
	Dermot	O'Rourke	Assessing the influence of cup material properties on the primary stability of cementless acetabular cups using finite element modelling
	Liesbeth	Klein	Randomized controlled study comparing the short Collum Femoris Preserving (CFP) and the Corail prosthesis
	Bart	Kaptein	An RSA RCT comparing two cemented fixed bearing knee designs
	Kjell G	Nilsson	Cemented vs uncemented fixation of a cruciate retaining femoral component in total knee replacement of patients younger than 60 years
	Andrew	Kurmis	Pseudotumor development around primary metal-on-metal THRs: the 'at risk' geneotype
Afternoon coffee & tea and poster viewing			
15:30-16:50	**First name**	**Surname**	**Abstract title**
JOINT SESSION Session chairs: Martin Downing, Donald Howie	Masako	Tsukanaka	Accuracy of measuring large dynamic movements with marker-based roentgen fluoroscopic analysis
	Vahidreza	Jafari Harandi	Muscle contribution to support during walking in transfemoral amputees
	Herman	Kaptijn	Polyethylene wear study on the non-cemented Triathlon CS total knee prosthesis
	Bita	Shareghi	Pelvic tilt between supine and standing after total hip replacement 106 patients examined with RSA up to 7 years after the operation
	Joseph	Hewitt	The early migration of porous tantalum acetabular components used at revision THR: a comparison of RSA and EBRA results
	Dhara	Amin	Radiostereometric analysis of internal disc strains during more physiologial simulation of repetitive lifting motions
	Petra	Heesterbeek	Stability and function of the Prodisc-C vivo cervical disc replacement: feasible with RSA?
16:50-17:00	President's closing address		

POSTERS on Day 1 (Friday October 06) – Level 8, Room 8D271
New Royal Adelaide Hospital, Corner North Tce & Port Rd, SA 5000

12:15-13:00	Lunch break		
14:50-15:20	Afternoon break		
Poster #	**First name**	**Surname**	**Abstract title**
4	Antonia RuJia	Sun	High carbohydrate high fat diet induced metabolic overload cause osteoarthritis-like changes of the cartilage and shift macrophage polarisation status in a rat model
8	Chelsea	Woo	Use of anodic oxidation to enhance the biocompatibility of tantalum implants
17	Danè	Dabirrhamani (Turner)	Biomechanics of stair descent in patients with knee osteoarthritis enrolled in TKA
23	Julia	Kuliwaba	Association between bone microstructure, microdamage, vascularity and bone marrow lesions in the subchondral bone of knee osteoarthritis
31	Jiao Jiao	Li	Osseointegrated Prosthetic Limb for the reconstruction of lower limb amputations: Outcomes at 1-year follow-up
33	Kent	Algate	Epigenetic regulation of human osteoblasts by inhibition of histone deacetylase 5 enhances markers of bone formation in vitro
37	Luisa	Schreck	Anti-microbial bioceramic coating on Ti6Al4V surfaces by anodisation
43	Nhiem	Tran	Novel antimicrobial coating for antiinfective medical devices
47	Rami M A	Al-Dirini	Influence of surgical variation in stem sizing and positioning on the primary stability of cementless femoral stems
53	Saulo	Martelli	Femoral fracture during side fall: sensitivity of dynamic finite-element models
59	Stuart	Millar	Understanding three-dimensional fracture patterns of the tibia and femur in orthopaedic trauma: estimating longitudinal and condylar axes on CT reconstructions of partial lengths and widths of bone
60	Thomas	Nottage	The effects of advanced glycation end prodcuts on the nano-structural properties of bovine cortical bone
62	Will	Robertson	Open source comparison of regression-based body segment parameter models
66	Zhibin	Du	Ovariectomy induced ultrastructure and mechanical property changes in rat‘s maxillary bone

POSTERS on Day 3 (Sunday October 08) – Level 8, Room 8D271
New Royal Adelaide Hospital, Corner North Tce & Port Rd, SA 5000

12:40-13:10	Lunch break		
15:00-15:30	Afternoon break		
Poster #	**First name**	**Surname**	**Abstract title**
22	Dhara	Amin	Serum metal levels after removal of spinal instrumentation
102	Andreas	Burger	A model-based radiostereometric analysis approach to measuring stability of a cementless metal-backed patella
107	Bart	ten Brinke	Long term follow-up after instrumented bone preserving total elbow arthroplasty using radiostereometric analysis
115	Jennifer	Hurry	The influence of subject and implant characteristics tibial component migration
120	Ian	Blom	Effective radiation dose and image quality in roentgen stereophotogrammetric analysis
121	Ioane	Vakaci	Application of torsional loads in ovine fracture models to measure stiffness with rsa
124	Jennifer	Hurry	Total knee arthroplasty RSA in the standing low-dose biplanar EOS x-ray imager
127	Joris E.	Meinardi	A selection of preliminary 1 year post-operative RSA-data of the Persona versus NexGen TKP-study: does the novel design perform just as well?
131	Kjell G	Nilsson	Monoblock posterior stabilized vs cruciate retaining trabecular metal tibial component
134	Koen	van Hamersveld	Migration and radiological appearance of uncemented Tritanium tibial components – One-year results of a randomised RSA study
149	Martin	Downing	Fully automated “live” RSA analysis in the radiography room: practical experience and comparison to manual measurement
150	Martin	Downing	Radiostereometric assessment of healing in proximal humeral fractures
153	Matthew	Teeter	Tibial component migration in total knee replacement performed using gap balancing and measured resection techniques
156	Petra	Heesterbeek	Feasibility of model-based RSA of the tibial component of bicruciate retaining TKA
159	Nils Oscar	Nivbrant	A prospective consecutive series assessing migration and rotation of the absolut cemented femoral stem
163	Janni Kjærgaard	Thillemann	Precision of bone models in dynamic RSA of the elbow and forearm
168	Thomas	Turgeon	Stability assessment of a new knee replacement product using radiostereometric analysis
171	Umberto	Cardinale	Kinematic evaluation of the Depuy Attune™ prosthesis using dynamic RSA

ABSTRACTS

DAY 1

KEYNOTE 1- Prof Stuart Goodmann

Session Sponsor

BONE DEFECTS IN THE 21st CENTURY: NEW PARADIGMS FOR ENHANCEMENT OF BONE HEALING

Stuart B. Goodman

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Residual bone defects are common in orthopaedics, especially in clinical scenarios such as trauma, infection, periprosthetic osteolysis, failed spinal fusion, osteonecrosis and others. Whereas smaller defects are readily dealt with using a variety of methods and implants, larger defects are more challenging. The gold standard is autologous bone graft, however in larger defects, this option may be limited in quantity or quality. Furthermore, the harvesting procedure is often painful and may be associated with adverse events at the harvest site. These facts have spawned recent efforts to gather together the three main elements essential for osteogenesis, including a suitable scaffold, stimulatory signals, and viable osteoprogenitor cells, by other means.

The development of optimal scaffolds for tissue engineering of bone has met with limited success. Indeed, recent in vivo models have provided strong evidence that mineralized decellularized cancellous bone allograft is probably the standard by which newer scaffolds should be compared. Growth factor based treatments are expensive, the results are often unpredictable and site specific, and large non-physiological doses are required for the desired effects. In addition, unwanted effects have been documented on other cells, and the use of growth factors can be associated with paradoxical osteolysis.

Perhaps the most promising, practical and translational techniques include the use of autologous concentrated bone marrow aspirate, often combined with a carrier or other scaffold. This treatment obviates the necessity for large incisions, and has been shown to be safe and effective for the treatment of nonunions and other conditions associated with bone defects.

Recent experiments performed in our and other laboratories have demonstrated that complex crosstalk occurs among cells of the mesenchymal stem cell (MSC)/osteoblast lineage and cells of the monocyte/macrophage/osteoclast lineage. Interactions between osteoblasts and osteoclasts have been well documented, however less is known about the modulation of osteoprogenitors by macrophages (mø). In vitro and in vivo research will be presented that firmly establishes the critical importance of MSC-mø interactions to bone healing [1-4]. These interactions are highly temporal dependent. The effects of aging of MSCs and mø significantly impacts the events of bone healing [5,6]. Finally, opportunities to modulate inflammation in order to facilitate bone healing and mitigate bone loss will be enumerated.

ACKNOWLEDGEMENTS

This work has been supported by NIH grants 2R01AR055650, 1R01AR063717, the Coulter Foundation, the Ellenburg Chair in Surgery at Stanford University, and the Jane and Aatos Erkko foundation.

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DAY 1

PODIUM 1- Joint Session

IMPLANT STIFFNESS AND PERI-PROSTHETIC CHANGES IN THE RAT MODEL

[1,2]Mengzhen Yan, [1]Dr. Rema Oliver, Ph.D., [1]Dr. Matthew Pelletier, Ph.D.,[1]Dr. Christos Christou, Ph.D., [2]Prof. Mark Hoffman, Ph.D. and [1]Prof. William Walsh, Ph.D.

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[2]School of Materials Science and Engineering, University of NSW, Sydney, NSW
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INTRODUCTION

A clinical problem of concern for the 1.8 million Australians needing joint replacement surgery [1] is thought to be stress-shielding of the bone due to the implant material. Whilst literature has compared the effects of implant stiffness and surface topography on osseointegration [2-3], greater understanding needs to be obtained in how bone structure, mechanical properties and biological behaviour is changed as a direct result of implant material properties.

METHODS

The rodent femur was used as a model to evaluate the effect of implant stiffness via insertion of Titanium (Ti), Stainless Steel (SS) and Nitinol (NiTi) implants into intramedullary canals of 16 week old female Sprague Dawley rats in randomised manner with sham and non-surgical control groups. 4 and 12 weeks post-operative, animals were euthanized, AP and LAT x-rays were graded along with measurement of femoral length and isthmus. Nanoindentation was performed on dehydrated and PMMA embedded cortical bone at anterior (A), posterior (P), medial (M) and lateral (L) sites at 5000 µN. Additionally paraffin and PMMA histology were obtained.

RESULTS AND DISCUSSION

Surgery and implantation influenced longitudinal bone growth. The difference between treatments was most prominent at 12 weeks post-operative where non-treated groups were significantly longer than those with sham surgery or stainless steel implants. Differences of up to 6% were also noted between legs with different treatments where all non-treated contralaterals were equal to or longer than operated legs. Isthmus diameter was reduced due to thickening of the cortex associated with endosteal and periosteal bone deposition; surgery, age and implant were all statistical factors. Intramedullary canal diameter decreased with time and was exacerbated with surgery and implant stiffness. Structural changes were observed with surgery and implantation affecting condyle shape in addition to trabecular structure and premature growth plate closure. At 12 weeks, non-treated bone was stiffer and significantly harder than implanted counterparts. A, L, M and P site specific stiffness and hardness changes further suggest age, surgery and implant stiffness to be important variables.

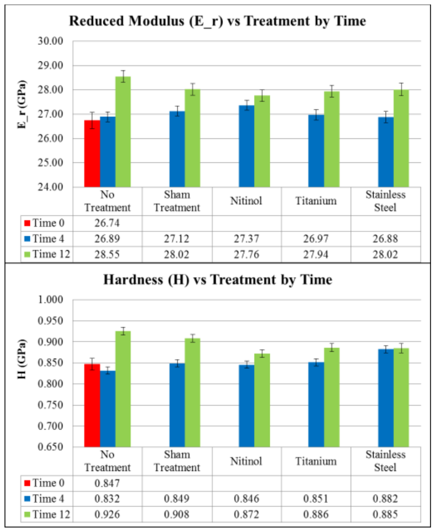

Figure 1: Reduced Modulus and hardness of bone as a factor of implant stiffness and treatment time.

CONCLUSIONS

The rat femur is a viable model to explore stress shielding related phenomenon. The implant modulus influences bone remodeling geometrically and at the material level.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Tian Wang for his help with the x-ray grading, Mr. John Rawlinson and Mr. Gregory Mitchell for their animal care and husbandry and Mr. Bill Joe for his help with the nanoindenter. We also thank all staff and students from the School of Materials Science and Engineering and Surgical and Orthopaedic Research Laboratory.

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TEN YEAR MIGRATION AND INDUCIBLE DISPLACENT OF CEMENTED AND UNCEMENTED TIBIAL COMPONENTS

[1,2]Elise Laende, [2]Michaela Wallace, [2]Glen Richardson, and [1,2]Michael Dunbar

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[2]Division of Orthopaedic Surgery, QEII Health Sciences Centre, Halifax NS, Canada
email: elaende@dal.ca

INTRODUCTION

Studies of implant migration have typically focused on early migration in the first two post-operative years as previous studies have shown this to be predictive of long-term fixation. We had the opportunity to test this conclusion with different implant designs than those previously included in predictive RSA studies as we had a cohort of subjects with RSA beads implanted who were more than 10 years from their knee replacement surgery. The objective of this study was to compare implant migration and inducible displacement at ten years to the migration results in the first two post-operative years.

METHODS

Subjects who had previously participated in RSA migration studies with 2 year follow-up were recruited to return for a long-term follow-up exam, at least 10 years from their surgery. The implants under study included two cemented designs (Advance® Knee System, Wright Medical Technologies Inc., Memphis TN and NexGen® Option Stemmed, Zimmer, Warsaw, IN) and one uncemented design (NexGen® Trabecular Metal™ ("TM") Monoblock, Zimmer, Warsaw, IN). At the 10 year visit, subjects had supine RSA exams to determine long-term migration as well as a loaded exam (single leg stance) to determine inducible displacement.

RESULTS AND DISCUSSION

Seventy-five subjects were available for long-term follow-up, with average time since surgery of 12 years. This cohort contained 51 women and 24 men with cemented tibial components in 53 cases (37 female) and uncemented tibial components in 22 cases (14 female). At the time of surgery, the subjects were 62±7 years old with BMIs of 33±6 m/kg^2 (mean±standard deviation). Median migration at the long-term follow-up was 0.6 mm (MTPM; range 0.2-2.8 mm) and was not different between the cemented and uncemented groups (p = 0.9, Mann Whitney U Test).

Inducible displacement at 10 years was significantly lower for the uncemented implants (Figure 1).

Migration at one, two, and 10 years did not correlate with inducible displacement at 10 years. However, migration at one year and two years did correlate with long-term migration, with the strongest correlation at two years (Figure 2).

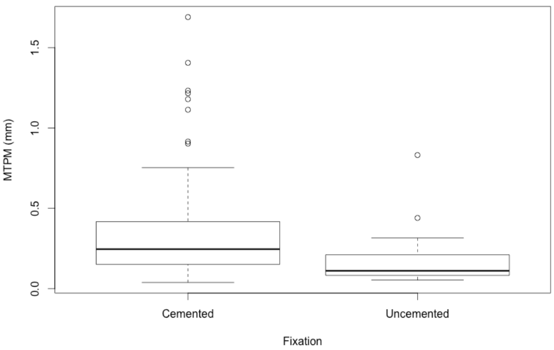

Figure 1: Inducible Displacement for cemented (n=53) and uncemented (n=22) tibial components at a minimum of 10 years from surgery. Between group differences p<0.001 (Mann Whitney U Test).

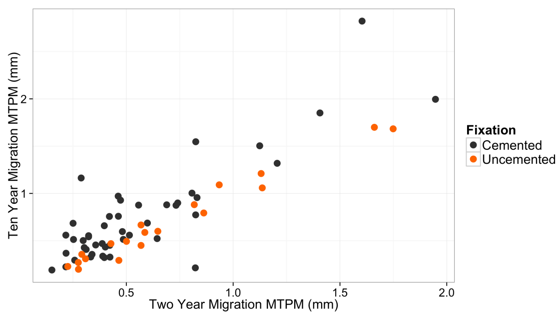

Figure 2: Two year vs. 10 year migration (MTPM). Spearman's rank correlation coefficients: All subjects: rho = 0.74 (p < 0.001), cemented components: rho = 0.67 (p<0.001), uncemented components: rho = 0.95 (p<0.001).

CONCLUSIONS

Although long-term migration was not different for cemented or uncemented (TM Monoblock) tibial components, inducible displacement at the 10 year visit was significantly lower for these uncemented components. Additionally, long-term migration was strongly correlated to two year migration, regardless of fixation. These findings support the predictive value of short-term migration in determining long-term fixation.

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   Authors have received institutional research support from orthopaedic manufacturers (Stryker, DePuy, Wright Medical, Smith&Nephew, Zimmer).

PERFORMANCE OF HIGHLY CROSSLINKED POLYETHYLENE CUP IN TOTAL HIP ARTHROPLASTY

Evaluation of wear and fixation during 2 years using RSA

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INTRODUCTION

Wear of the acetabular cup has been a problem ever since the introduction of the hip prosthesis. Acetabular cups are made of ultra-high molecular weight polyethylene (UHMWPE). By cross-linking UHMWPE, creating highly cross-linked polyethylene (HXLPE), wear-induced cup damage, peri-prosthetic osteolysis and aseptic loosening can be reduced. Bearing in mind the importance of properly evaluating new medical products before launching them into the health care system, we here wanted to examine the performance of a new acetabular cup – the Link Ticona GUR 1020 HXLPE device – by comparing it with the standard Link Chirulene GUR 1020 UHMWPE device (ConvPE). Wear and fixation were measured using radiostereometric analysis (RSA).

METHODS

In a prospective randomized controlled trial (RCT), 59 patients (60 hips), mean (range) age 71 (51-85) years with primary osteoarthritis were enrolled. At operation, randomization was performed with regard to a cup made of HXLPE or UMWHPE. Baseline RSA examination was performed 2-4 days after surgery, and 3, 12, and 24 months postoperatively. Wear was measured as proximal head penetration, 2D-head penetration, as well as 3D-head penetration, using both postop and 3 months investgigations as reference. Annual wear rate was calculated between 1 and 2 years. Quality of fixation of the cup was measured as rotation of the cup in relation to acetabulum.

RESULTS

After 2 years, the mean (95% CI) proximal head penetration for the HXLPE was 0.11 (±0.03) mm and 0.17 (±0.06) mm for the ConvPE. Mean 3D wear was 0.18 (±0.05) mm for the HXLPE and 0.23 (±0.05) mm for the ConvPE. Wear seemed to taper off after 1 year for the HXLPE cups, whereas this did not occur for the ConvPE cups (Fig. 1). Annual proximal wear rate calculated between 1 and 2 years was 0.01 mm for the HXLPE group and 0.04 mm for the ConvPE group. After 2 years, migration of the cup was greater in the study group across all three rotation axes, but none of the differences were statistically significant.

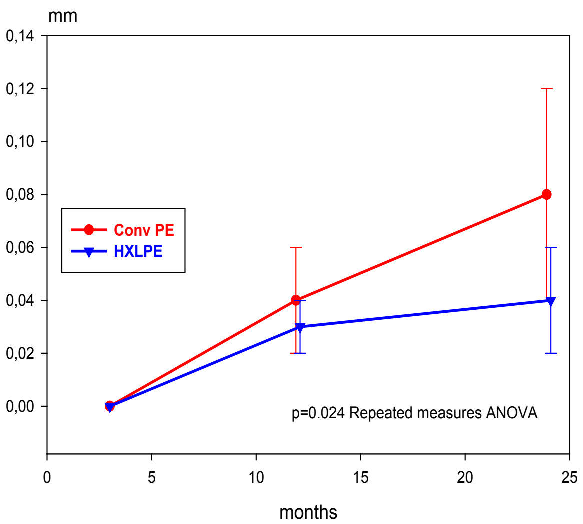

Figure 1: Proximal head penetration (Y-axis wear) in the Conventional polyethylene (ConvPE) and Highly Cross-linked polyethylene (HXLPE) groups.

DISCUSSION

At the 2-year follow-up, the study showed reduced wear in the HXLPE cup compared to the UHMWPE cup. The finding is in line with what was expected, namely that the new plastic will provide better wear reduction. The improved wear resistance was not obtained at the expense of fixation.

ACKNOWLEDGEMENTS

This study was funded in total by Link, Germany

<u>CONFLICT OF INTEREST DECLARATION</u>

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

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   The study was funded by Link, Germany

THE EFFECTS OF VITAMIN E AND POLYETHYLENE WEAR PARTICLES ON OSTEOCYTES *IN VITRO*: IMPLICATIONS FOR PERIPROSTHETIC OSTEOLYSIS

[1]Renee T Ormsby, [1]Kunihiro Hosaka, [2]Tania N Crotti, [2]David R Haynes, [1]Andreas Evdokiou, [1]L. Bogdan Solomon, [1]David M Findlay and [1]Gerald J Atkins.

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INTRODUCTION

The development of osteolytic lesions associated with total hip replacement surgery is a major cause of implant failure. Formation of these lesions has been directly linked to the production of wear particles from the articulating surfaces of prostheses. Polyethylene (PE) liners, which commonly serve as the bearing surface of implant prostheses, produce bioactive wear particles through mechanical friction, as well as through oxidative processes catalysed within the body. Newer designed polyethylene liners are imbued with vitamin E, a naturally occurring antioxidant, to prevent oxidative degradation of the PE, however the biological effects of particulates of this material is not well known. We have shown that osteocytes, the major cell type in the bone, respond to PE particles *in vitro* by inducing osteocytic osteolysis related genes (*MMP13*, Cathepsin K, *CA2*), and promoting osteoclastic bone resorption by upregulating the *RANKL:OPG* ratio [1]. In this study we investigated potential interactions between osteocytes exposed to PE wear particles in the presence or absence of vitamin E.

METHODS

Normal human bone cells (NHBC) derived from trabecular bone biopsies from patients undergoing THR surgery were differentiated to a mature osteocyte-like phenotype over 28d. The NHBC were then overlaid with a collagen gel (Cellmatrix, Type 1-A, Nitta) containing UHMWPE (Ceridust) +/- Vitamin E (α-Tocopherol or γ-Tocotrienol) particles and cultured for a further 21d. RNA was extracted and subjected to real time RT-PCR analysis.

RESULTS AND DISCUSSION

As previously published [1], PE particles upregulated mRNA expression of osteocytic-osteolysis related genes (*MMP13*, *CA2*, *CTSK*). The addition of either Vitamin E analogue; α-Tocopherol or γ-Tocotrienol, alone, as well as in combination with PE particles, also resulted in significant upregulation of these genes. PE particles upregulated the pro-osteoclastogenic gene expression ratio *RANKL:OPG* [1], however this was significantly decreased by either vitamin E analogue. All treatments upregulated key antioxidant enzymes *SOD1*, *SOD2* and Catalase, which are important for regulating oxidative stress. These findings suggest that release of Vitamin E from the PE liners, either free or attached to wear particles, could play an important role in protecting the bone from the osteoclastogenic response to wear particles but conversely may stimulate osteocyte driven osteolysis and contribute to aseptic loosening.

CONCLUSIONS

This study shows that Vitamin E may play an important role in regulating bone remodeling, and could contribute to the development of osteolysis and consequent aseptic loosening.

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EARLY IN VIVO WEAR MEASUREMENT OF 98 TOTAL KNEE REPLACEMENT PATIENTS USING RADIOSTEREOMETRIC ANALYSIS

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INTRODUCTION

Total knee replacement (TKR) is a highly successful operation used to treat end stage knee arthritis. The articulation of the polyethylene (PE) insert between the metal femoral and tibial components can wear, leading to revision surgery. Recent advancements in PE manufacturing have resulted in improved wear resistance and implant longevity measured *in vitro* on wear simulators. However, such wear tests may not accurately predict *in vivo* wear. We sought to assess *in vivo* wear of modern PE inserts in TKR using model-based radiostereometric analysis (MBRSA).

METHODS

Ethics approval was obtained from both the University of Manitoba and Dalhousie University Research Ethics Boards. We obtained MBRSA films on 106 patients who underwent primary TKA in Halifax, NS. Radiographs were obtained post-operatively and at 6-, 12-, and 24-months. All patients received a Stryker Triathlon TKR with a fixed, conventional PE insert of either a cruciate retaining (CR) or posterior stabilized (PS) design. Patient age, gender, and body mass index were also collected.

In order to assess *in vivo* wear, we developed highly accurate 3-dimensional virtual models of each *in vivo* TKA for each follow-up time point for each patient. Computer models of the tibial and femoral components were obtained through reverse engineering while models of the PE inserts were provided by the manufacturer. Cartesian coordinate data for the tibial and femoral component models was obtained through MBRSA analysis and used to position the implants models in 3-dimensional space. PE insert models were then inserted between the tibial and femoral models to facilitate wear analysis. Linear PE insert wear was measured as the change in joint space from post-operative to 24 months. Volumetric insert wear was measured as the change in overlapping volume between the femoral component and the tibial insert models from post-operative to 24 months.

Wear was considered for medial and lateral sides independently. A linear best-fit was applied to wear data for each patient to determine an annual rate of wear. Individual wear rates were combined to calculate a mean rate of wear for the PE inserts. Wear data was compared against patient demographics for evidence of statistical correlation.

RESULTS AND DISCUSSION

The mean linear wear rate for 98 patients was virtually zero for both the medial and lateral condyles (Table 1). Conversely, mean volumetric wear rate was 10.4 mm^3/yr (SD: 20.8 mm^3/yr), with the majority of wear occurring on the medial side. Further, linear wear analysis resulted in twice as many patients with measured negative wear rates compared to volumetric wear assessment. Measured wear did not correlate significantly to patient age or body mass index (Pearson Correlation: $R<0.14$, $p>0.05$). Gender did not show a significant effect on measured wear (Student's t-test: $p>0.05$).

CONCLUSIONS

Linear PE wear measurement was found to be less reliable than volumetric methods as evidenced by higher occurrence of negative wear rates. Volumetric PE wear measurement using MBRSA determined an annual wear rate of 10.4 mm^3/yr. The standard deviation of this measurement was twice that of the calculated mean, indicating that this methodology can feasibly detect TKR wear on conventional PE inserts within 2-3 years if adequately powered. Limitations of this study include: patient imaging was performed supine as opposed to standing, patient activity level is unknown and cannot be controlled for, and analysis of double-exams has yet to be performed to determine clinical precision limits.

Table 1: Mean wear per medial and lateral sides with sum total. Percent negative wear indicates the number of patients with a measured wear rate <0 mm/yr or mm^3/yr.

Variable	Medial	Lateral	Sum Total
Linear wear rate Mean, (SD)	0.01 (0.23) mm/yr	-0.04 (0.16) mm/yr	-
Negative linear wear rate (%)	41%	56%	-
Volumetric wear rate Mean, (SD)	9.5 (16.4) mm^3/yr	2.4 (12.7) mm^3/yr	10.4 (20.8) mm^3/yr
Negative volumetric wear rate (%)	20%	34%	28%

<u>CONFLICT OF INTEREST DECLARATION</u>

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

If you have accepted any support such as funds or materials, tangible or intangible, concerned with the research by the commercial party such as companies or investors, choose YES below, and state the relation between you and the commercial party.

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1. The author(s) did receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity.

   One author (MD) is a consultant for Stryker Orthopaedics. No payments or benefits were received as a direct result of this study.

2. A commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

   Stryker Orthopaedics provided in-kind support by supplying CAD models of implants. No payments or funding were received from Stryker Orthopaedics relating to this study.

IMAGE-BASED METHOD TO ASSESS LOCAL CHANGES IN CORTICAL THICKNESS IN THE MOUSE TIBIA LOADING MODEL, WITH AND WITHOUT ADMINISTRATION OF PTH

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INTRODUCTION

The most efficient anabolic strategies to increase bone mass are based on physiological loading, either directly through mechanical loading (e.g., exercise) or via pharmaceutical intervention, such as intermittent administration of parathyroid hormone (PTH) [1,2]. Micro-CT is the gold standard for assessing the effect of loading on bone structure. One approach is to perform ex-vivo imaging, after sacrificing the animal at the end of the experiment (end-point imaging). Bone variables are evaluated for the entire cross-section and used to statistically compare the loaded limb with the contralateral one. Micro-CT images of cortical bone qualitatively show that bone adaptation occurs locally at the periosteal surface [1]. However, with this approach, the local adaptation response cannot be quantified. As an alternative, in-vivo longitudinal imaging and image co-registration can be used. However, the excessive exposure of animals to radiation and anesthesia, and the large amount of data accumulation are limitations of this latter methodology. The aims of this study are: (i) to calculate local bone adaptation quantities on the cross-section, as opposed to average values reported in previous studies; (ii) to link these local changes in cortical thickness to mechanical quantities, such as the strain energy density (SED); (iii) to investigate the individual and the combined effects of mechanical loading and PTH treatment on local bone adaptation.

METHODS

Ex-vivo, high-resolution micro-CT images (4.78 µm pixel size) of mouse tibiae were used in this study. Four cortical sites of interest were selected, namely *proximal* (25% of total bone length from proximal end), *proximal/middle* (37%), *middle* (50%) and *distal* (75%). Images of these sites were used to quantify geometric properties of bone cross-sections, such as cortical thickness, centroid position and principal axes. Image binarization was performed using Otsu's method. Filtering was applied to close small holes (i.e., blood vessels) and to smooth periosteal and endosteal boundaries. A MATLAB algorithm was developed to compute bone thickness at each periosteal pixel. Depending on the shape of the cross-section, this algorithm measured the thickness in two alternative ways: minimum periosteum-endosteum distance or thickness along the direction normal to the periosteum. To compare the thickness changes due to different loadings and between different animals, we developed an alignment procedure along the periosteum length. The intersection between the periosteum and the line connecting tibia and fibula centroids was used as reference point. Depending on the analysed site, cortical thickness measurements along the periosteum were aligned using either cross-covariance or peak-to-peak resampling. A micro finite element model of the mouse limb and a MATLAB algorithm were developed to compute the SED at the periosteum, in the 4 sites of interest.

RESULTS AND DISCUSSION

Figure 1 shows the thickness measurement in the cross-section (left) and the relative thickness variation along the periosteum (right) calculated at the middle site, for a peak mechanical load of 10 N. The shaded area (right) indicates variability between animals (n=6). This analysis quantified the local bone adaptation occurring in specific areas of the periosteal surface.

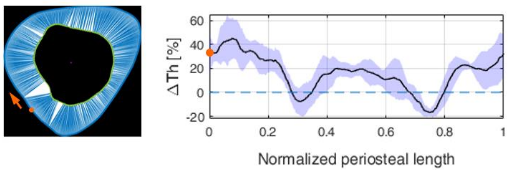

Figure 1: Cortical thickness measurement (left) and relative thickness variation along the periosteum (right) at the middle site (50%) for a peak load of 10 N.

CONCLUSIONS

The developed image post-processing algorithm was used to calculate cortical thickness changes from ex-vivo mouse tibia micro-CT imaging data. Results indicate that bone adaptation following the application of a mechanical load is local and higher in periosteal regions with higher SED. This finding confirms that bone adaptation to exercise is localized and suggests that it is driven by the local mechanical environment. The effect of PTH on the local adaptation of cortical bone is currently being investigated. From a preliminary analysis, it appears that the administration of PTH leads to a more uniform bone gain on periosteal surfaces.

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STERILISATION OF ACETABULAR GRAFT: INTERIM RADIOSTEREOMETRY RESULTS

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INTRODUCTION

The impaction of allograft bone into areas of bone loss during hip revision surgery has become a standard procedure. Due to concerns about potential viral and prion transmission, a novel chemical sterilisation procedure has been developed jointly by the SNBTS (Scottish Blood Transfusion Service) and the NHSBT (NHS Blood and Transplant) which aims to preserve the biological and mechanical properties of the bone. This study compares in revision hip surgery, the migration and inducible movement of cemented acetabular components impacted with either processed allograft bone or standard fresh frozen bone.

METHODS

Patients were aged 50 to 80, having a first revision of cemented THR, and with acetabular defects suitable for impaction grafting. They were randomized to either fresh frozen or processed bone. RSA was carried out on the AdoraRSA (NRT, Denmark) using Canon CXDI-50C detectors, and calibration box 43 (RSA Biomedical AB, Sweden) in an upright setting.
RSA exams were taken at 1, 6, 13, 26, 52, 104 weeks with patient standing with the imaged leg bearing 50% of body weight (+/- 5%). At 1, 6 and 13 weeks, the patients received an additional examination with no weight on the imaged leg. Consequently movement of the cup with respect to the pelvis will be seen as "recoil" as the force of 50% body weight through the hip is released. We refer to the movement between these exams as induced movement. Weight through the operated leg during imaging was monitored using wireless force plates.

Variable	n	mean	min	max	medabs	rms	prec95%
TRL_X	10	0.003	-0.037	0.042	0.015	0.024	0.054
TRL_Y	10	0.001	-0.040	0.031	0.014	0.020	0.046
TRL_Z	10	-0.011	-0.069	0.046	0.045	0.039	0.088
ROT_X	10	-0.016	-0.162	0.070	0.045	0.064	0.145
ROT_Y	10	0.042	-0.171	0.217	0.068	0.109	0.246
ROT_Z	10	0.005	-0.095	0.109	0.031	0.053	0.120

Table 1. Precision of the cup movement with respect to the pelvic bone for non weight bearing exams

RESULTS AND DISCUSSION

Table 1 shows the estimate of clinical precision of the cup position measurement, calculated from planned repeat exams taken at 13 weeks with full repositioning. There was no difference between the precision weight bearing and non-weight bearing, implying the cup induced movement is elastic.
Two distinct modes of cup migration were observed which can be described as high migrators (HM) and low migrators (LM) (figure1). We defined HM as those with 13 week superior migration greater than 0.5mm. In the figures fresh frozen graft is identified by triangles, and processed bone by squares. HM are coloured red or orange, whereas LM blue or green.
Superior migration of more than 0.5mm was noted in 3 subjects. Migration continued throughout the observed times, but with progressively reducing rate (figure 3). For the other 7 patients, there was less than 0.2mm total superior migration.

Figure 2 shows the superior induced movement. At 1 week, all the subjects have detectable induced translational movements *in one or more axes*. At 6 weeks this reduced to only 50% of the LM and 67% of the HM. At 13 weeks no LM but all HM have detectable movements, and for the HM it is increasing in either superior or medial direction. These observations imply that while there is some induced movement initially for impaction grafting, it reduces rapidly (within 13 weeks) for normal cases (LM), whereas it increases between 6 and 13 weeks for cases which go on to migrate highly (HM). It would be interesting to explore in a future study the extent of induced migration for high migrators at later time points.
The rate of migration is shown in figure 3. For all except the HM group and subject 2 the rate of migration falls below the detectability limit by 13 weeks. While the rate of movement has decreased progressively over time for all including the high migrators, the 2 year data on subject 3 indicates it is still migrating, which may become clinically important.

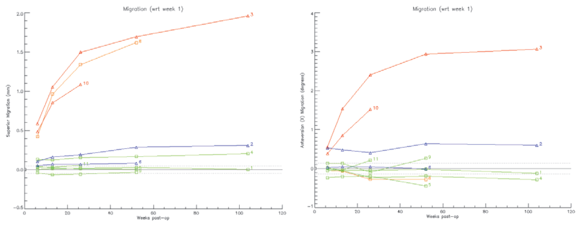

Figure 1: Migration. Superior (a) and anteversion (b).

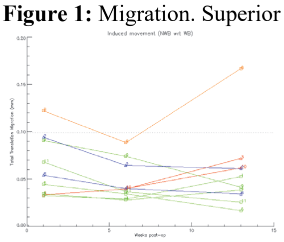

Figure 2: induced movement.

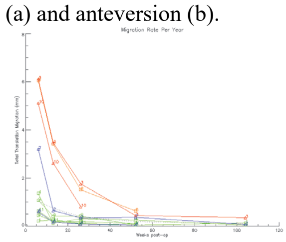

Figure 3: rate of migration.

CONCLUSIONS

The majority of cups were very stable with inducible micromotion less than 0.1mm and migration less than 0.25mm. 3 cups migrated more than 0.5mm but with continually reducing rate.
There was no difference identified between graft types.

ACKNOWLEDGEMENTS

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DAY 1

PARALLEL PODIUM 1- ANZORS Session

TWIST-1 REGULATED MICRORNA-376C IS A NOVEL PLAYER IN MESENCHYMAL STEM CELL GROWTH AND OSTEOGENIC DIFFERENTIATION.

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INTRODUCTION

The proliferation and differentiation of mesenchymal stem cells (MSC) is tightly regulated by multiple pathways that lead to the activation of specific transcription factors. Among these is the basic helix-loop-helix (bHLH) transcription factor TWIST-1. Bone marrow derived MSC (BMSC) and cranial cells (CBC) express TWIST-1, an important mediator of skeletal and head development. BMSC over-expressing TWIST-1 display decreased capacity for osteogenic differentiation [1]. Twist-1 mutant heterozygote mice display abnormal craniofacial and skeletal structures. These abnormalities are replicated in a human childhood disorder known as Saethre–Chotzen syndrome (SCS) which is caused by a mutation in the *TWIST-1* gene [2]. Loss of TWIST-1 function in CBC results in increased osteogenic differentiation leading to premature fusion of cranial sutures and SCS. This implicates TWIST-1 as a key regulator of BMSC and CBC proliferation and osteogenic differentiation. An increasing number of studies have demonstrated the involvement of microRNAs (miRNAs) in the proliferation and or osteogenic differentiation of MSC. Twist-1 is known to regulate the expression of the miR-199/214 cluster during mouse development [3]. However, no BMSC and CBC specific miRNAs regulated by TWIST-1 have previously been studied. We have identified a novel TWIST-1 regulated miRNA, miRNA-376c and have examined its function in BMSC and CBC.

METHODS

BMSC and CBC were isolated with appropriate ethics approval and cultured *in vitro* in growth or osteogenic inducing media [1]. miRNA array profiling using an eukaryote Affymetrix chip array and quantitative real time PCR (qPCR) was performed to determine miRNA-376c expression in these cells during differentiation. Chromatin immunoprecipitation (ChIP) was performed to determine whether an E-box site within the regulatory region of miRNA-376c was a TWIST-1 binding site. Over-expression of miRNA-376c in BMSC and CBC was achieved using miRNA-376c mimics and assays were performed to detect altered osteogenic potential [1]. Expression of miRNA-376c, osteogenic markers and IGF-1R were determined by qPCR and Western Blot Analysis. Bromodeoxyuridine (Brdu) incorporation assay was used to detect proliferating cells.

RESULTS AND DISCUSSION

Expression of miRNA-376c was down-regulated in BMSC and CBC during osteogenic differentiation, but was increased by TWIST-1. Furthermore we found that loss of TWIST-1 expression in BMSC and CBC resulted in decreased levels of miRNA-376c when compared with wild type cells. Functional *in vitro* studies demonstrated that over-expression of miRNA-376c reduced cellular proliferation and resulted in a decreased capacity for osteogenic differentiation. During osteogenic differentiation, miRNA-376 was shown to inhibit Insulin-like growth factor 1 receptor (IGF-1R) expression. IGFR signalling has previously been shown to mediate bone progenitor cell proliferation and differentiation [4].

CONCLUSIONS

We have identified miRNA-376c as a novel target of TWIST-1 which is expressed in BMSC and CBC. miRNA-376c negatively regulates cellular proliferation. It also plays a role in BMSC and CBC osteogenic differentiation through the down regulation of IGF-1R signalling. This study is the first to identify a TWIST-1 regulated miRNA important for proliferation and osteogenic differentiation, and will help define the processes that mediate MSC growth and fate determination. Further studies may lead to the development of miRNA synthetic therapies for bone defects in the skeleton and the cranium caused by *TWIST-1* mutations.

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LOSS OF EPHRINB1 IN OSTEOPROGENITORS LEADS TO AN OSTEOPOROTIC PHENOTYPE IN MICE

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INTRODUCTION

The largest receptor tyrosine kinase family, the Eph receptors and their ephrin ligands have been implicated in processes of skeletal development and bone homeostasis in humans and using mouse models. Specifically, our studies showed that osteogenic differentiation was enhanced when ephrinB1 expressing human mesenchymal stem cells (MSC), were stimulated with the cognate EphB2 receptor[1]. Conversely, loss of ephrinB1 by osteoprogenitors in mice, resulted in deficient endochondral ossification and enhance osteoclast formation during skeletal maturation[2]. The destabilization of bone homeostasis was found to compromise bone formation and integrity. The present study therefore examined the influence of ephrinB1 during bone homeostasis following the onset of osteoporosis.

METHODS

Bone samples were analyzed from female mice that underwent ovariectomised-induced osteoporosis (OVX) or sham surgery (citing ovaries). Female C57BL/6 mice OVX and sham mice were assessed by RT-PCR for ephrinB expression. Homozygote ephrinB1 (*EfnB1)* conditional knockouts under the control of the osterix promoter (*Osx:EfnB1*$^{-/-}$) and *Osx:Cre* controls were assessed for skeletal tissue parameters using 3D µCT and 2D histomorphometric analysis of the distal femora. Methacrylate embedded femoral sections were used to visualize Calcein labelling or stained with toluidine blue or TRAP. Flow cytometric analysis was used to identify osteogenic populations. Human *in vitro* osteoclast differentiation studies utilizing soluble ephrinB1-Fc were performed and assessed by RT-PCR and TRAP enumeration to understand the involvement of Eph-ephrinB1 signaling in osteoclast function.

RESULTS AND DISCUSSION

Femora isolated from sham and OVX induced female C57BL/6 mice demonstrated that ephrinB1 was significantly down-regulated in OVX compared to sham samples. Subsequent osteoporosis studies were carried out in EfnB1 conditional knockouts (*Osx:EfnB1*$^{-/-}$) and *Osx:Cre* controls. The loss of ephrinB1 alone in sham treated mice impaired trabecular architecture comparable to OVX *Osx:Cre* control mice. However, the osteoporotic phenotype was not further exacerbated in OVX *Osx:EfnB1*$^{-/-}$ females (Figure 1). The osteoporotic phenotype in sham treated *Osx:EfnB1*$^{-/-}$ mice associated with a significant decline in osteoblast numbers and bone formation rate; and elevated osteoclast numbers within the trabecular bone when compared to sham *Osx:Cre* controls.

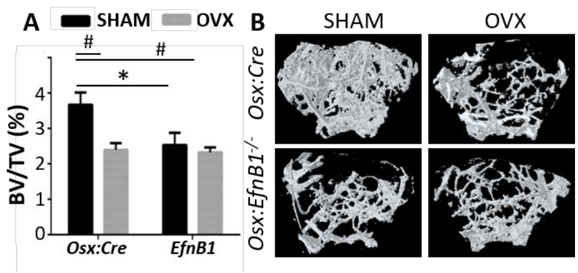

Figure 1: Loss of EfnB1 in osteoprogenitors induces an osteoporotic bone phenotype. (A) µCT analysis and (B) representative images of *Osx:Cre* and *Osx:EfnB1*$^{-/-}$ (*EfnB1*) mice that underwent sham (black) or ovariectomy (OVX, grey) surgery. (n = 6-8 mice/condition/strain, * p<0.05, # P<0.01, 2-way ANOVA, multiple comparisons).

Subsequent *in vitro* human osteoclast differentiation studies demonstrated that EphB2, was the highest expressing EphB receptor. Furthermore, the stimulation with soluble ephrinB1-Fc during osteoclast differentiation, resulted in significantly fewer multinucleated TRAP^{+} osteoclasts when compared to Human-Fc controls.

CONCLUSIONS

Our findings indicate that bone integrity may be in part maintained through ephrinB1 signaling. Where alterations in ephrinB1 signaling lead to an imbalance in bone remodeling.

ACKNOWLEDGEMENTS

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ROLE OF *HOPX* IN BMSC PROLIFERATION AND DIFERENTIATION

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INTRODUCTION

Bone marrow-derived mesenchymal stem cells (BMSC) are self-renewing, multipotent cells that can give rise to multiple lineages including osteoblasts (bone), chondrocytes (cartilage) and adipocytes (fat). Interestingly, various pathways that promote BMSC osteo/chondrogenesis simultaneously suppress adipogenesis and vice versa [1, 2].

The bHLH transcription factor, TWIST-1 is highly expressed by BMSC and plays an important role in BMSC self-renewal and differentiation. Enforced expression of TWIST-1 enhances proliferation potential and lifespan of BMSC. It also enhances the adipogenic potential of BMSC yet inhibits chondrogenesis and osteogenesis [3-5]. However, many of the underlying mechanisms mediating TWIST-1 regulation of BMSC growth and differentiation still remain poorly understood.

In order to identify novel TWIST-1 gene targets involved in BMSC proliferation and osteogenic differentiation, microarray analysis was performed to compare the gene expression profile of BMSC which express either endogenous or enforced expression of *TWIST-1* during growth culture conditions or undergoing osteogenic differentiation. One novel differentially expressed gene was *HOPX* [5]. *HOPX* encodes for a hop homeobox protein important in cardiogenesis [6, 7]. Currently, no known function of *HOPX* has been identified during BMSC growth or differentiation. We aim to determine whether *HOPX* is a novel target of TWIST-1 in BMSC and thus possibly be involved in mediating the effects of TWIST-1 on cell proliferation and lineage commitment.

METHODS

STRO1$^+$ MSC were isolated from the bone marrow aspirates from the posterior iliac crest of adult donors and cultured in vitro in growth, osteogenic or adipogenic inducing media as previously described [4]. Quantitative real time PCR (qPCR) using SYBR Green was used to determine *HOPX* expression. In silico analysis of the upstream regulatory region of *HOPX* and chromatin immunoprecipitation (ChIP) assay was performed to determine the presence of TWIST-1 binding sites. Knock-down of *HOPX* in human BMSC was achieved using silencer select siRNAs and assays were performed to detect altered proliferation rate, adipogenic and osteogenic potential as previously described [4].

RESULTS AND DISCUSSION

Microarray analysis demonstrated that *HOPX* is expressed in BMSC. qPCR was performed to validate the microarray and demonstrated that *HOPX* expression is reduced in TWIST-1 expressing cells when cultured in osteogenic and adipogenic conditions. This demonstrated a negative correlation between *TWIST-1* and *HOPX* and suggested that *HOPX* may play a role during BMSC osteo/adipogenesis. In silico analysis revealed two putative TWIST-1 binding sites (E-boxes) at 700bp and 2.9kb upstream of *HOPX* transcription start site. ChIP assay was performed and demonstrated that TWIST-1 binds to at least one of the E-boxes in the promoter region of *HOPX* when BMSC is cultured in normal growth media. To investigate the function of *HOPX* during BMSC osteo/adipogenesis, knock-down experiments were performed. A knock-down efficiency of ~90% was achieved. Reduced *HOPX* expression in BMSC cultured in adipogenic inducing media resulted in an increased number of Oil Red O and Nile red positive, lipid producing cells when compared to control. In addition, there was an increase in the expression of adipogenic markers. However, there was no effect on the osteogenic potential of BMSC when cultured in osteogenic inducing media. Moreover, knocking-down *HOPX* decreased the proliferation rate of BMSC compared to control.

CONCLUSIONS

Our data demonstrates for the first time that TWIST-1 negatively regulates *HOPX* expression in BMSC. Moreover, reduced *HOPX* gene expression in BMSC lead to an increase in the adipogenic potential of these cells and decreased proliferation rate. Thus, our results suggest that *HOPX* could have an important function in BMSC proliferation and adipogenic differentiation. Further studies including luciferase reporter assay and overexpression of *HOPX* are required to further investigate the roles of *HOPX* in these cells.

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GH insensitivity disrupts cell cycle progression in the growth plate in Mucopolysaccharidosis VII mice

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INTRODUCTION

A progressive skeletal dysplasia that includes short stature is a hallmark of 6 of 11 types of mucopolysccharidoses (MPS), a group of inherited lysosomal disorders [1]. Affected children show minimal long bone growth after 2 years of age with a final height z-score -3 to -6 SD below normal [2]. Current therapies for MPS patients have a limited effect on bone growth. Long bones grow through the process of endochondral ossification (EO), which is strictly regulated by systemic factors such as growth hormone/insulin-like growth factor 1 (GH/IGF1) and thyroid hormone (T3) [3]. These factors, along with other paracrine and transcription factors tightly regulate the cell cycle in the growth plate as chondrocytes divide and then exit the cell cycle for hypertrophy. Our previous study showed that in the murine MPS VII model final long bone length was greatly reduced, while growth plate height increased, the number of chondrocytes in the proliferative (PZ) and hypertrophic zone (HZ) significantly decreased. However, the mechanism underlying the dysregulated bone growth in MPS patients is not fully understood.

METHODS

Immunohistochemistry was carried out on D14 normal and MPS VII proximal tibia. Antibodies to CyclinD1, Ki67, $p57^{kip2}$ and phosphorylated histone H3 (pHisH3) were used and the % of cells positive for each antibody in each zone of the growth plate was determined. Circulating GH, IGF1, IGFALS, IGFBP3 and T3 was measured in normal and MPS VII serum by ELISA. IGF1 production of normal and MPS VII hepatocytes in response to GH stimulation was detected by ELISA. Real-time RT-PCR was performed using cDNA reverse transcribed from RNA isolated from liver or whole growth plate or PZ of the growth plate.

RESULTS AND DISCUSSION

Ki67 antigen, a maker for all active phases of the cell cycle, was expressed throughout the growth plate, and the number of cells positive for Ki67 increased significantly in all zones in MPS VII. G1 phase marker Cyclin D1 and M phase marker phosphorylated histone H3 were predominantly observed in the PZ of normal growth plate indicating progression to mitotic division. These markers were not observed in the normal HZ where cells expressed $p57^{kip2}$ indicating cell cycle withdrawal. In contrast, the number of PZ chondrocytes expressing pHisH3 decreased to 63% of normal (Fig. 1, $p<0.05$) in MPS VII, while MPS VII HZ chondrocytes continued to express CyclinD1 along with a reduced number of cells positive for $p57^{kip2}$ (51% of normal, Fig.1, $p<0.05$). Thus fewer chondrocytes were capable of entering mitosis or exiting the cell cycle to progress to the hypertrophic stage in MPS VII growth plate. This observation was supported by real-time PCR analysis which indicated a 2-fold reduction in the expression of pre-hypertrophic marker *Ihh* in the MPS VII growth plate and a 4.4-, 3.1- and 4.4- fold increase in *PTHrPR, Sox9* and *Wnt5a* respectively, which prevent conversion of proliferating to hypertrophic chondrocytes.

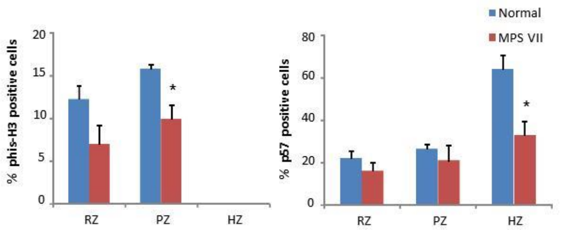

Figure 1: Quantitative analysis of cell cycle regulation in normal and MPS VII growth plate. Antibodies to A) pHisH3; B) $p57^{kip2}$ was used for IHC. RZ=resting zone; PZ=proliferative zone; HZ=hypertrophic zone. * denotes to $p<0.05$, student's t-test.

IGF1 promotes G1/S cell cycle progression through CyclinD1 and $p57^{kip2}$. In young MPS VII mice, circulating IGF1 was significantly reduced to 42% of normal, while GH and T3 levels were normal, suggesting GH insensitivity in MPS VII. The molar ratio of IGF1: IGFBP3: IGFALS changed from 1:3.5:4.4 in normal mice to 1:6.1:4.4 in MPS VII mice, indicating a reduction of free IGF1 in MPS VII. The reduction in circulating IGF1 was due to a decreased ability of MPS VII hepatocytes to produce IGF1 in response to GH stimulation. This was not due to lack of gene expression of *Ghr* or *Stat5a/5b*.

CONCLUSIONS

The pace of cell cycle progression in MPS VII chondrocytes is disrupted, decreasing proliferation and delaying the transition to hypertrophy. This may be attributed to GH insensitivity in MPS VII mice. Our findings suggested that the balance of cell cycle regulation and GH/IGF1 signaling pathway play important roles in impaired linear bone growth in MPS VII mice.

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Identification of genes regulating osteoarthritis development using a mouse phenotype library

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INTRODUCTION

Osteoarthritis is a degenerative joint disease with a slow progression. Treatment is limited to pain management and physiotherapy to maintain mobility, a total joint replacement is the only treatment for cases of severe OA. Investigation of OA affected cartilage is conducted via radiographic imaging, arthroscopy and/or post joint replacement surgery; therefore observing disease progression in humans is difficult. It has been suggested that the development of spontaneous OA has a strong genetic component which has had limited investigation in isolation thus far. Therefore the identification of biomarkers associated with spontaneous OA development and risk are of high importance to understand the mechanism of the disease.

METHODS

We have utilised a mouse phenotype library, the collaborative cross, to assess affected cartilage microscopically across a spread of ages. Mice >12 months were selected for the initial cohort. These strains were screened using histology to assess and score the severity of OA in knee joints using the OARSI grading scale. The strains were ranked from lowest to highest and the data used to map genetic variation that was consistently associated with the highest OA scores. Tissues from strains that had consistent high scores were further investigated using qPCR to investigate the expression of genes that were identified in the mapping process.

RESULTS AND DISCUSSION

Mapping from the first forty strains have demonstrated a range of OA incidence as observed in human populations (Figure 1). Two strains have been identified as having consistently high OA scores irrespective of gender. Based on gene mapping data, variation in the *Zfhx4* gene was identified to be uniquely associated with the identified strains. It was revealed that *Zfhx4* is highly upregulated during chondrocyte maturation in a rabbit cell based microarray study.

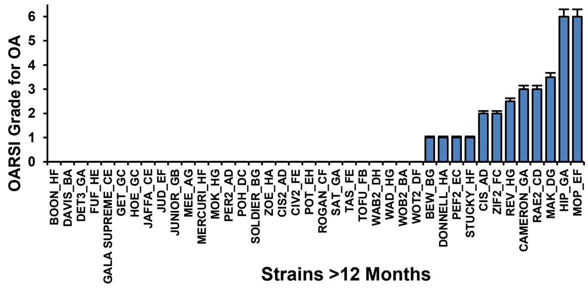

Figure 1: OARSI score of OA severity across collaborative cross strains.

CONCLUSIONS

The observed spontaneous occurrence of OA in the collaborative cross supports the argument of genetic contribution to the development of the disease. The association of *Zfhx4* with chondrocyte differentiation indicates that *Zfhx4* is a candidate gene for the regulation of OA development. There are currently no known genes associated with spontaneous OA in animal models. The availability of mouse models to investigate spontaneous OA will allow better understanding of the mechanism of disease inheritance and progression and might be of great value to identify biomarkers for OA diagnosis and treatment.

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Peter Robbins.

FLAVONOID GENISTEIN POTENTIALLY PROTECTS BONE MARROW SINUSOIDAL BLOOD VESSELS AND ENHANCES THEIR RECOVERY FOLLOWING METHOTREXATE THERAPY IN RATS

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INTRODUCTION

Bone marrow micro-vascular system is composed of sinusoids which are mono-layered with sinusoidal endothelial cells (SECs). Bone marrow sinusoidal endothelium plays a key role in orchestrating various physiological functions including bone formation and bone remodelling. Previous preclinical and clinical studies have shown that cancer chemotherapy is a major extrinsic stimulus which can cause bone marrow sinusoidal damage. Thus, investigations are required to address whether and how bone marrow sinusoidal endothelium can be protected or its recovery promoted following cancer chemotherapy. Herein, in a rat model, we examined the potential protective effect of genistein, a soy-derived flavonoid, against bone marrow sinusoidal damage caused by treatment with methotrexate (MTX) which is a widely used anti-metabolite for cancer treatment.

METHODS

Groups of young adult rats were treated with 5 daily MTX injections (0.75 mg/kg) with and without genistein oral supplementation till day 9 after the first MTX injection. Histological analyses on bone marrow blood vessel alterations were conducted on left tibia of rats. qRT-PCR assays were also conducted to examine changes in expression of angiogenesis-related genes in the bone. Additionally, in vitro studies were performed to investigate the viability, proliferation, tube formation ability, and nitric oxide production of primary sinusoidal endothelial cells (SECs) with or without treatment with genistein.

RESULTS AND DISCUSSION

Our histological analyses showed that the diameters of bone marrow sinusoids in MTX alone-treated group were significant enlarged compared to the normal or genistein alone treated controls. However, unlike those in the MTX alone-treated group, bone marrow sinusoidal endothelium in the genistein + MTX group were not damaged. qRT-PCR assays showed higher levels of expression of angiogenesis marker CD31 and angiogenic growth factor VEGF in the bone and bone marrow of rats treated with genistein alone and genistein + MTX compared to MTX alone treated rats. Our in vitro studies also showed that, while genistein did not affect the viability of cultured SECs, in certain concentrations it protected the SECs from cytotoxic effect of MTX. Furthermore, genistein was found to stimulate tube formation in cultured SECs, which was associated with enhanced expression of endothelial nitric oxide synthase and production of nitric oxide in cultured SECs.

CONCLUSIONS

The results of this study suggest that genistein might have a potency to protect bone marrow sinusoidal endothelium during/following MTX therapy.

ACKNOWLEDGEMENTS

This work was supported by funding from University of South Australia, NHMRC, and Channel-7 Children Research Foundation.

FLAVONOID ICARIIN ATTENUATES METHOTREXATE CHEMOTHERAPY-INDUCED BONE LOSS AND BONE MARROW SINUSOID DAMAGE IN RATS AND STIMULATES MIGRATION AND FORMATION OF MICRO-VESSEL LIKE TUBES IN CULTURED SINUSOIDAL ENDOTHELIAL CELLS

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INTRODUCTION

Cancer chemotherapy has been reported to negatively affect the homeostasis of bone and bone marrow and cause damage to the bone marrow micro-vascular system, for which effective treatments are lacking. Icariin, an herbal flavonoid, has been widely shown to be beneficial for treating many diseases including osteoporosis and cardiovascular dysfunction. In the present study, we examined the potency of icariin in attenuating bone loss and damage of bone marrow micro-vascular system sinusoids caused by treatment of methotrexate (MTX) which is a commonly used anti-metabolite in cancer chemotherapy.

METHODS

Groups of young adult rats were treated with 5 daily MTX injections (0.75 mg/kg) with and without icariin oral supplementation until day 9 after the first MTX injection. Histological analyses were performed to investigate the alterations in the structure and volume of tibial trabecular bone and damage/dilation of bone marrow sinusoids. qRT-PCR assays were also conducted to study the treatment effects on expression of osteogenesis-, adipogenesis-, and angiogenesis-related genes in the bone of treated rats. Additionally, *in vitro* studies were performed to address icariin treatment effects on the viability, proliferation, nitric oxide production, tube formation and migration of cultured primary sinusoidal endothelial cells.

RESULTS AND DISCUSSION

Following MTX treatment, histological analyses revealed a significant reduction in the bone volume/tissue volume fraction (%) and trabecular number in the metaphysis trabecular bone of treated rats, but no significant changes in trabecular thickness and trabecular spacing. However, the bone volume/tissue volume (%) and trabecular number were found to be significantly higher in MTX + icariin-treated rats than those of MTX alone-treated rats. Gene expression analyses showed that icariin treatment maintained expression of osteogenesis-related genes but suppressed the induction of adipogenesis-related genes in bones of MTX–treated rats. In addition, icariin treatment attenuated MTX-induced dilation of bone marrow sinusoids and upregulated expression of endothelial cell marker *CD31* in the metaphysis bone of icariin + MTX-treated rats. Furthermore, *in vitro* studies suggest that icariin treatment can potentially enhance the survival of cultured rat sinusoidal endothelial cells against cytotoxic effect of MTX and promote their migration and tube formation abilities, probably via promoting production of nitric oxide.

CONCLUSIONS

Our results suggest a potential role of flavonoid icariin in attenuating MTX-induced bone loss and a direct and/or indirect role in reducing MTX-induced damage of bone marrow micro-vessels sinusoids. Thus icariin may has a potential role in preventing bone loss and maintaining angiogenesis in the bone marrow during or following MTX treatment.

ACKNOWLEDGEMENTS

This work was supported by funding from University of South Australia, NHMRC, and Channel-7 Children Research Foundation.

INJURY SITE DERIVED-NEUROTROPHIN-3 AS A NOVEL CROSS-TALK SIGNAL INDUCES VEGF AND PROMOTES ANGIOGENESIS AND BONY REPAIR AT INJURED GROWTH PLATE

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INTRODUCTION

A better understanding of the regulatory signals for injury repair events, particularly in situations with impaired bone healing /non-union of fractured bones or with faulty bony repair/bone bridge formation at children's injured growth plate, will improve strategies for overcoming impaired bone healing and non-unions or preventing growth plate faulty repair. While some previous studies have suggested that neurotrophins (including NGF, BDNF, NT-3 and NT-4) and their receptors may be involved in regulating bone repair, their roles and action mechanisms in bone/growth plate repair remain largely unclear.

Recently, we observed increased injury site mRNA expression of neurotrophins NGF, BDNF, NT-3 and NT-4 and their Trk receptors, with NT-3 (NT-3 >100-fold, others <35-fold) and its receptor TrkC showing the highest induction, during bony repair at growth plate injury site [1]. The current study investigated potential roles and action mechanisms of injury site-derived NT-3 in modulating angiogenesis during growth plate bony repair.

METHODS

Using in vitro cell models and a rat proximal tibial growth plate drill-hole injury repair model, we investigated potential functions and action mechanisms of NT-3 in angiogenesis and bony repair in the growth plate injury site.

RESULTS AND DISCUSSION

In rat proximal tibial growth plate injury site, NT-3 was localized to repairing cells (stromal cells, osteoblasts and chondrocytes) at day 8 after the injury, and at later stages most prominently on osteoblasts on newly formed bone surface, while receptor TrkC was observed in stromal cells, osteoblasts and blood vessel cells at the injury site. Systemic NT-3 immunoneutralization reduced vascularization and bone volume at the growth plate bony repair site as examined on both days 10 and 28. Conversely, recombinant NT-3 treatment promoted vascularization and bony repair at the injury site, with elevated levels of mRNA expression for endothelial cell marker CD31 and vascular endothelial growth factor (VEGF), and for osteogenic markers. When examined *in vitro*, rhNT-3 promoted osteogenesis in rat bone marrow stromal cells, and enhanced expression of BMPs (particularly BMP-2) and VEGF in the mineralizing cells. Consistent with its angiogenic effect *in vivo*, rhNT-3 promoted angiogenesis in metatarsal bone explants, an effect abolished by co-treatment with anti-VEGF. Furthermore, in cultured rat primary endothelial cells, rhNT-3 also induced CD31 and VEGF mRNA and formation of blood vessel-like tubes.

CONCLUSIONS

Our studies suggest that injury site-derived NT-3 may be an important upstream regulator of bony repair of injury growth plate, which can induce BMP-2 and VEGF and thus promote bony repair and vascularization at the injury site.

ACKNOWLEDGEMENTS

This work was supported by funding from University of South Australia, NHMRC, and Channel-7 Children Research Foundation.

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DAY 1

PARALLEL PODIUM 1- RSA Session

Equal fixation of fixed-bearing versus mobile-bearing cemented partial knee replacement.
A randomised controlled RSA study with 2-year follow-up

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INTRODUCTION

Medial unicompartmental knee arthroplasty (UKA) makes up 10-20% of all knee arthroplasties and gives good clinical outcomes. However, the revision rate is higher compared to total knee arthroplasty (TKA)[1]. Early implant migration is a predictor of implant loosening/revision and can be measured with radiostereometric analysis (RSA). The mobile-bearing Oxford UKA has been on the marked for 40 years and has a 7-year revision rate of 11.1%, and a 10-year revision rate of 14.9% [2]. The fixed-bearing Sigma UKA has been on the marked since 2010 and presents a low 7-year revision rate of 5.5% in registries. Longtime follow up for the Sigma UKA is yet unknown.

This study aims to **evaluate migration** of the **Sigma** and **Oxford UKA** using RSA.

METHODS

A patient-blinded, randomised controlled RSA study with 24 months follow-up was performed. Between January 2014 and October 2015, 62 patients were randomised to receive either a Sigma (N = 31) or Oxford UKA (N = 31). Stereoradiographs were obtained postoperatively, at 4, 12 and 24 months. Model-based RSA software was used to measure tibial component migration. Mixed model analysis was used for statistical data evaluation. Currently, follow-up is completed for 43 patients, and complete follow is expected at the time of the conference.

RESULTS AND DISCUSSION

Translations and rotations for the tibial component at 24 months follow-up are shown in table 1. No difference in migration was found between the Sigma UKA and the Oxford UKA. The size of measured translations and rotations was comparable with reportings in the literature [2]. Figure 1 shows the maximal total point motion (MTMP) of the tibial component of the Sigma UKA and the Oxford UKA. No difference was shown between groups (Likelihood ratio test) ($p = 0.9$). A difference in migration over time was found for both groups ($p < 0.01$).

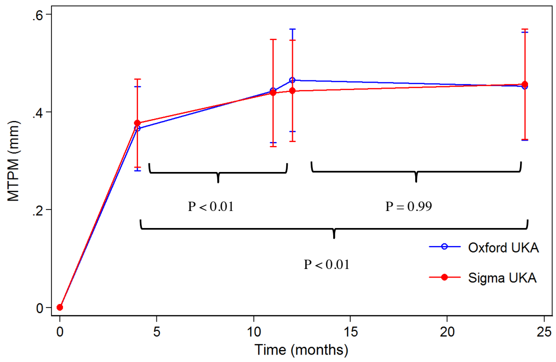

Figure 1: MTPM with 95% confidence intervals are shown for the Sigma and Oxford UKA with 24 months follow up.

CONCLUSIONS

Our study shows no difference in migration between the Sigma UKA and the Oxford UKA. This supports the low revision rates of the Sigma UKA in the national registries [2]. Migration stabilises after 12 months.

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Table 1: Mean translations (95% CI) and rotations (95% CI) of the Sigma and Oxford UKA at 24 months.

Model	**Translations (mm)**			**Rotations (°)**		
	X	**Y**	**Z**	**X**	**Y**	**Z**
Sigma UKA	0.06 (0.02; 0.11)	0.09 (0.01; 0.13)	-0.08 (-0.24; 0.07)	-0.45 (-0.73; -0.17)	-0.02 (-0.29; 0.24)	-0.21 9-0.38; 0.21)
Oxford UKA	0.08 (0.04; 0.13)	0.04 (-0.02; 0.10)	-0.08 (-0.23; 0.08)	-0.42 (-0.70; -0.15)	0.13 (-0.14; 0.39)	-0.21 (-0.38; -0.04)

SIMILAR MIGRATION IN COMPUTER-ASSISTED AND CONVENTIONAL TOTAL KNEE ARTHROPLASTY A MULTICENTER, PARALLEL-GROUP, RANDOMIZED CONTROLLED TRIAL INVOLVING 54 PATIENTS

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INTRODUCTION

Computer-assisted surgery (CAS) in total knee arthroplasty (TKA) has been used in recent years in the hope of improving the alignment and positioning of the implant, thereby achieving a better functional outcome and durability. However, the role of computer navigation in TKA is still under debate. We used radiostereometric analysis (RSA) in a randomized controlled trial (RTC) to determine whether there are any differences in migration of the tibial component between CAS- and conventionally (CONV-) operated TKA.

METHODS

This RSA study was part of a larger RCT investigating clinical and radiological outcome after TKA operated with either CAS or CONV technique.[1] The first 54 patients, mean age 67 (56-78) years, with osteoarthritis or arthritic disease of the knee, were marked with RSA markers (CAS, n=26, CONV, n=28). The. Patients were recruited from 4 hospitals during the period 2009-2011. 6 tantalum-sphere markers 0.8 and 1.0 mm (diameter) were inserted into the polyethylene component of the tibia and 9 markers (1.0 mm) were spread out into the tibial metaphysis (figure 1). To estimate the mechanical stability of the tibial component, RSA analysis were done up to 24 months after operation. The following parameters representing tibial component micromotion were measured: 3-D vector of the prosthetic marker that moved the most, representing the magnitude of migration (maximum total point motion, MTPM); the largest negative value for y-translation (subsidence); the largest positive y-translation (lift-off); and prosthetic rotations. The precision of the RSA measurements was evaluated and migration in the 2 groups was compared.

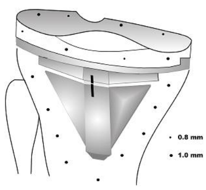

Figure 1: Distribution of tantalum markers in the polyethylene component of the prosthesis and tibia metaphysis.

RESULTS

Both groups had most migration within the first 3 months after surgery and then appeared to stabilize. There was no statistically significant difference in the magnitude of the migration between the CAS- and the CONV group. From 3 to 24 months the MTPM was 0.058 mm and 0.102 mm ($p = 0.1$) for the CAS and CONV groups, respectively (Figure 2). No tibial components migrated more than 0.1 mm between 12 and 24 months. The component that migrated most had an MTPM of 0.09 mm during the second year of observation. There were no outliers. The total rotational migration (in degrees) was similar between groups at all four follow-up times. There was no trend of any 1-directional migration pattern; we found an even distribution between positive and negative migration values in both groups. There were no statistically significant differences between the groups for maximal subsidence and lift-off between 3 months and 2 years. The mean error of rigid-body fitting was 0.12 (95% CI:0.11-0.13) and the condition number was 30 (95% CI:34-40).

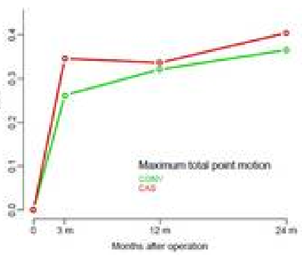

Figure 2: Maximum total point motion.

CONCLUSIONS

Mean MTPM, subsidence, lift off and rotational movement of tibial trays were similar in CAS and CONV operated knees.

ACKNOWLEDGEMENTS

The study was financially supported by the Research Council of Norway and South-Eastern Norway Regional Health Authority.

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PREOPERATIVE SYSTEMIC BONE QUALITY DOES NOT AFFECT TIBIAL COMPONENT MIGRATION IN KNEE ARTHROPLASTY. A 2 YEAR RSA STUDY OF 101 CONSECUTIVE PATIENTS

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INTRODUCTION

Bone quality and other preoperative predictive factors may affect the survival of knee arthroplasty. Early implant migration in the first 2 postoperative years measured with Radiostereometric Analysis (RSA) has been shown to predict long-term implant survival of knee arthroplasty [1,2].

METHODS

Longitudinal case study investigating predictors of tibial component migration at 2 years postoperative follow up in 101 patients with total knee arthroplasty (TKA) or unicompartmental knee arthroplasty (UKA). Predictors comprised clinical risk factors for osteoporosis, blood samples, DXA and the grade of osteoarthritis. Migration of the tibial components were measured with Model-based RSA. Investigated components were: cemented NexGen Stemmed tibial component, cementless NexGen trabecular-metal Monoblock tibial component, and cemented Oxford medial unicompartmental tibial component. Clinical outcome was evaluated with Oxford Knee Score (OKS).

RESULTS AND DISCUSSION

The 101 included patients (65 females) had a mean age of 67.7 years (range 39-87). Fifteen patients had osteoporosis (T-score $\leq$ -2.5) and 86 patients had osteopenia or a normal BMD. According to defined migration threshold (0.54mm) for maximum total point motion (MTPM) for tibial components at 1 year [2], 52.5 % had a migration below the “acceptable” treshold, and the remaining tibial components were considered “at risk” for later premature revision. There was no difference in mean total OKS scores at 1 year follow up between patients with tibial component migration >0.54mm MTPM compared to patients with tibial component migration <0.54mm MTPM (p=0.65). We found no difference in tibial component MTPM at 2 years (all 3 implant types combined) for patients with osteoporosis compared to patients without osteoporosis (p=0.34). Implant sub-type tibial component MTPM migration was also alike for patients with and without osteoporosis.

Sub-type implant mean MTPM migration is shown in figure 1. The cemented NexGen Stemmed tibial components and the cementless NexGen Monoblock tibial components migrated more than the cemented medial Oxford UKA tibial components, but in general the mean migration of the tibial components in this large consecutive patient group did not migrate more than reported in the literature for tibial components of similar types in patients that were selected by more study criteria, and excluding patients with poorer health. As expected cementless tibia components migrated the most, and subanalysis of migration in patients with low BMD should be further explored because the osteoporosis group was small.

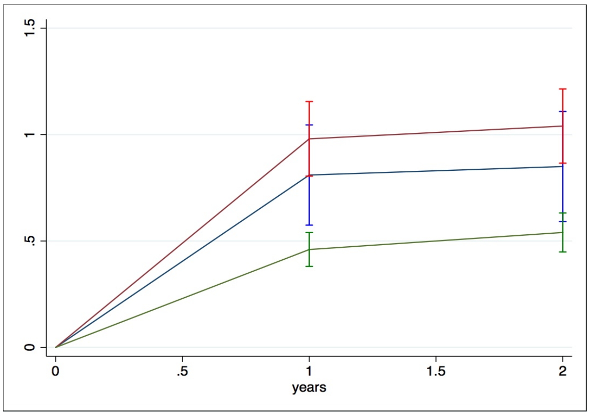

Figure 1: Mean MTPM (mm) postoperative and 1 and 2 years follow up. Error bars represent 95% Confidence Interval. Red line is the NexGen Monoblock, blue line is the NexGen Stemmed and the green line is Oxford UKA.

CONCLUSIONS

Migration of tibial components inserted with or without bone cement was not affected by the preoperative bone quality in terms of systemic BMD, bone turnover markers and local osteoarthritis grade in the knee.

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<u>CONFLICT OF INTEREST DECLARATION</u>

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   We received a grant from the Innovation Fund Denmark (Grant# 69-2013-1), a public fund, used for datacollection.
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   NONE

RSA-studies on a customized metal implant for cartilage lesions in the knee

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Introduction

Managing focal cartilage injuries in the middle-aged patient poses a challenge. A customized femoral condyle implant for focal cartilage injuries was designed to precisely be able to fit each patient´s individual size and location of the damage. The double coated, titanium-hydroxyapatite, Co-Cr implant has shown firm and consistent osseo-chondro-integration in an animal model (1), This implant system was modified to humans where the implant, femoral guide and a dummy instrument were patient specific from MR-images and CAD/CAM reconstruction. We here report on the RSA-results of the first 10 cases in order to assess fixation of the double-coated implant in a clinical environment.

Methods.

Ten patients were followed for two years. Mean age was 42,5 (range 36-56) years, All surgeries were done on the medial femoral condyle. 7 ICRS grade 4 and 3 ICRS grade 3 injuries, implant size 17 mm in 4 patients and 20 mm in 6 patients.
The implants were modified so that the tip of the pin was a perfect hemisphere. The translations of the centre of this hemisphere was measured relative to 4-6 tantalum beads inserted in the same condyle

Results

At 6 months, 1 year and 2 years, respectively, X-axis translation was a mean(mm) 0, -0.09 and -0.04, Y-axis translation was -0.03, 0.03 and 0 whereas Z-axis translation was 0.03, -0.12 and -0.06. The MTPM vector was 0.16, 0.32 and 0.27 mm, respectively. All but one implant was were perfectly stable after 6 months while the last case stabilized after 12 months.

Discussion

The HA-on-top-of titanium coating proved to provide satisfactory long-term fixation of these un-cemented, press-fit implants. Titanium fixation of tooth implants routinely last 20-years+. Unlike tooth implants, knee implants cannot be unloaded for a post-operative period of fixation processes. HA has been shown to permit loads/micromotion and still provide biological fixation (2). These RSA results corroborate the the hypotheses behind the double coating to be valid also in the human clinical situation.

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IMPLANT MIGRATION FOLLOWING TOTAL KNEE REPLACEMENT USING CONVENTIONAL OR PATIENT SPECIFIC INSTRUMENTS

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INTRODUCTION

Patient specific instrumentation (PSI) for total knee replacement (TKR) has demonstrated mixed success in simplifying the operation, reducing its costs, and improving limb alignment [1]. Evaluation of PSI with tools such as radiostereometric analysis (RSA) has been limited, especially for cut-through style guides providing mechanical alignment. The primary goal of the present study was to compare tibial component migration following TKR using conventional instruments (CI) and PSI based surgical techniques.

METHODS

The study was designed as a prospective, randomized controlled trial of 50 patients, with 25 patients each in the PSI and conventional groups, powered for the RSA analysis. Patients in the PSI group received an MRI and standing 3-foot x-rays to construct patient-specific cut-through surgical guides for the femur and tibia with a mechanical limb alignment (Visionaire, Smith & Nephew, Memphis, USA). All patients received the same posterior-stabilized implant (Legion, Smith & Nephew) with marker beads inserted in the bone around the implants to enable RSA imaging. Patients underwent supine RSA exams at multiple time points (2 and 6 weeks, 3 and 6 months, and yearly). One year data was currently available for 44 patients. Migration of the tibial component was calculated using model-based RSA software [2]. WOMAC, SF-12, EQ5D, and UCLA outcome measures were recorded pre-operatively and post-operatively at follow-up visits.

RESULTS AND DISCUSSION

At 1 year, there was no significant difference in MTPM of the tibial component (p = 0.30, Figure 1) between the CI group (0.61 ± 0.34 mm) and the PSI group (0.51 ± 0.27 mm). There was also no significant difference for any translation or rotation within the individual planes of migration (Table 1). There were no significant differences between groups for the WOMAC, SF-12, EQ5D, or UCLA Activity Scores at 1 year.

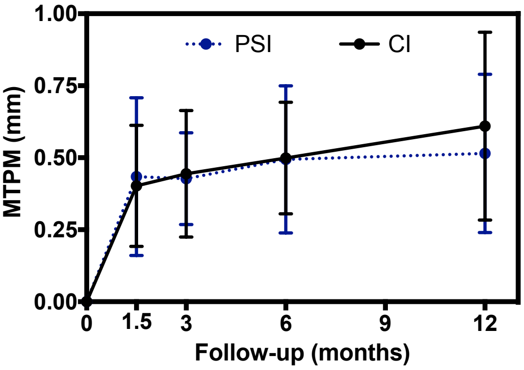

Figure 1: Maximum total point motion (MTPM, in mm) over 1 year post-operation. Error bars are standard deviation.

CONCLUSIONS

At 1-year RSA follow-up, the two groups were statistically indistinct with respect to implant fixation. However, using the Pijls et al. [3] criteria for acceptable early migration predictive of <3% revision rate at 5 years, the PSI group is considered acceptable (<0.54 mm of MTPM) while the CI group is at the low end of the at risk category (>0.54 to <1.6 mm of MTPM). Both groups reported improvements in outcome scores. Complete follow-up to 2 years post-operation is ongoing.

ACKNOWLEDGEMENTS

This study was funded by the Canadian Orthopaedic Research Legacy Grant from the Canadian Orthopaedic Foundation.

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Table 1: Translations (in mm) and rotations (in deg) within individual planes at 1 year, reported as mean ± standard deviation.

	Tx	Ty	Tz	Rx	Ry	Rz
CI	-0.01 ± 0.12	0.01 ± 0.08	0.01 ± 0.23	-0.06 ± 0.44	-0.13 ± 0.70	0.03 ± 0.27
PSI	0.05 ± 0.13	-0.01 ± 0.12	0.01 ± 0.13	-0.06 ± 0.31	0.05 ± 0.61	-0.01 ± 0.26
p Value	0.16	0.50	0.64	0.74	0.35	0.43

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   Smith & Nephew provided the cutting guides without cost.

   Dr. Howard is a paid consultant to DePuy and Stryker. Dr. Vasarhelyi is paid consultant to DePuy. Dr. McCalden is a paid consultant to Smith & Nephew. Dr. Naudie is a paid consultant to Microport, Smith & Nephew, and Stryker.

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   London Health Sciences Centre receives institutional research support from DePuy, Smith & Nephew, and Stryker.

Cementless versus cemented tibial fixation in posterior stabilised total knee replacement - a randomised trial

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INTRODUCTION

Evidence increasingly supports cementless tibial fixation in TKR but a paucity of literature exists for posterior stabilised designs.

This randomised clinical study compares how cemented or cementless tibial fixation impacts on component migration, bone remodelling and clinical outcomes in 100 Posterior Stabilised (PS) Total Knee Replacements (TKRs).

METHODS

This is a prospective single-centre blinded randomised clinical trial, involving 97 TKRs with a mean patient age of 68. Operations were divided across two experienced arthroplasty surgeons using ACS PS TKR prostheses (Implantcast). Patients were randomised to cemented or cementless tibial fixation. All other variables were standardized.

Dual-Energy X-ray Absorptiometry (DEXA) and Radiostereometric Analysis (RSA) were performed postoperatively and at 3, 12 and 24 months to monitor bone mineral density (BMD) and component migration. Patient Reported Outcome Measures (PROMs) including Oxford Knee Score and the Short Form-12 were assessed prior to surgery and at 3, 12 and 24 months.

RESULTS AND DISCUSSION

At 3 months the mean subsidence of the cementless group is 0.84mm (N=33) in contrast to the cemented group at 0.01mm (N=33) (p=<0.001). Migrations on other axes are not statistically significant nor are rotations.

During the 3-12 month interval decreasing subsidence is shown for the cementless implants (mean 0.20mm, N=29), while very little is shown in the cemented group (mean 0.03mm, N=37), (p=0.006). There is also a significant difference in rotation with cementless implants rotating into varus by mean 0.40 degrees versus 0.02 degrees in the cemented group (p=0.004).

Initial results for the 12-24 month interval show continuing subsidence in the cementless group (mean 0.18mm, N=26), while very little is shown in the cemented group (mean 0.02mm, N=32), (p=0.016). Again the cementless group exhibits varus rotation of mean 0.17 degrees versus -0.04 degrees in the cemented group (p=0.035). Late migration such as this is consistent with increased risk of revision.

Significant changes are also shown in tibial BMD over 24 months after surgery. Medial, lateral, posterior and anterior zones all show mean decreases in BMD in the cemented group in keeping with stress shielding while the cementless group shows a lesser decrease medially and mean increase in BMD for other zones.

PROMs are improving equally between groups and one tibial component has been revised to date after trauma.

CONCLUSIONS

Cementless tibial fixation of the ACS PS prosthesis is associated with late subsidence, raising concerns for fixation stability, while cemented implants display high initial and subsequent stability. BMD decreases are seen surrounding cemented components consistent with stress shielding, while the cementless group displays a mean conservation of BMD. Caution must be advised for this cementless PS tibial component.

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- Study funded by industry through Hollywood Private Hospital Research Foundation

DETERMINING THE FEMOROTIBIAL CONTACT POINT IN 90º FLEXION WITH MODEL-BASED RSA AFTER PCL-RETAINING TKA: FEASIBLE, STABLE, AND RELATES TO CLINICAL OUTCOME

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INTRODUCTION

Measuring the step off during total knee replacement (TKR) is a newly developed operative strategy [1] to determine the optimal contact point (CP) of the femur with the tibia postoperative and to balance the posterior cruciate ligament (PCL) in cruciate-retaining TKR. With this study we investigated whether the position of the medial and lateral CP in CR-TKA remained stable over time, and determined the relationship of the CP with clinical outcome.

METHODS

23 patients presenting with non-inflammatory osteoarthritis, a good functioning PCL, and indication for surgery with a PCL-retaining TKR were selected. Intraoperative PCL balancing was performed with the spacer technique [1]. At 3, 12, and 24 months postoperative, a pair of mediolateral radiographs was made using a set-up used for radiostereometric analysis (RSA). The patient was positioned standing with the operated leg in 90 degrees, 50% weight-bearing, knee flexion on a 30 cm-step. Model-based RSA software (RSAcore, Leiden, The Netherlands) was used to determine the 3D positions of the femur and tibia components, that were exported to custom-written software for determining the medial and lateral CP. Each CP was defined as the point with the smallest distance between the medial or lateral femoral condyle and tibia plateau. It is expressed as the ratio of the anterior-posterior CP distance and the maximum anterior-posterior tibia plateau size, with 0 being anterior, 1 being posterior. Differences between medial and lateral CP, for patients with/without flexion limitation, and changes over time were described.

RESULTS AND DISCUSSION

Preliminary data show that during follow-up, the medial CP moved to anterior, whereas the lateral CP remained stable. (Figure 1) This might indicate a slight stretching of the PCL over time. For all follow-up moments, the median medial CP was statistically significantly more anterior than the lateral CP ($p<0.023$), Table 1. Patients with flexion limitation (n=5) showed a more posterior medial CP at 24 months, compared with patients with no flexion complaints ($p=0.046$).

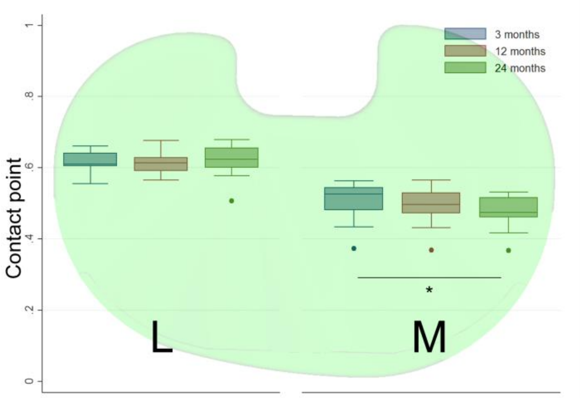

Figure 1: Projection of the lateral (left) and medial (right) CP on top of an insert.

CONCLUSIONS

The medial CP moves slightly anteriorly over time, whereas the lateral CP remains at a stable position (more posteriorly). The medial CP seems to relate to clinical outcome; patients with flexion limitation had a more posterior medial CP at 24 months after surgery. This might be an indication for a too tightly balanced PCL.

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Table 1: Contact point (ratio of CP/AP-size tibia plateau; median (min-max), 0 being anterior, 1 being posterior).

	3 months (n=23)	12 months (n=22)	24 months (n=18)
Medial CP	0.53 (0.37 – 0.56)	0.50 (0.37 – 0.57)	0.47 (0.37 – 0.53)
Lateral CP	0.61 (0.56 – 0.66)	0.61 (0.57 – 0.68)	0.62 (0.51 – 0.68)

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   Part of this study was financially supported by Smith & Nephew (payments to hospital, research department).
   Smith & Nephew was not involved in interpretation, analysis and presentation of the results of this study.

KINEMATIC EVALUATION OF THE ZIMMER PERSONA™ PROSTHESIS USING DYNAMIC RSA

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INTRODUCTION

The purpose of this work is to study the kinematics of the ZIMMER Persona™ Knee System FB PS during a daily life activity.
This model has a particular asymmetrical tibial plates, close to the physiological anatomy and it should affect the kinematic of the knee in a more natural way.
The motor task of the sit-to-stand from a chair was analyzed. This motor task is very common and allows to analyze the motion of the prosthesis with active muscle contraction and high stress inside the joint.

METHODS

The used RSA device was BiSTAND DRX (ASSING Group, Rome, Italy). The patients were asked to perform a sit-to-stand motor task: from the sitting position, the patient stands up.
The kinematic was analyzed using custom dedicated software. The motion parameters were evaluated using the Grood and Suntay [1, 2] decomposition and the Low-point kinematics [3]. The time was normalized in percentage (0% begin, 100% end of the motor tasks). A random cohort of 8 randomly selected patients was operated and evaluated after 9 month follow up. The mean age of the patients was 69 years (95%CI, 64-82).

RESULTS AND DISCUSSION

The kinematical data of the examined motor task were analyzed and shown in figures 1.

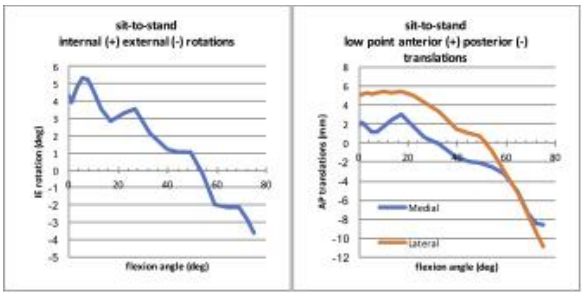

Figure 1: IE (left) and Low point (right) plots of the sit-to-stand movement.

The IE rotation show a trend from external to internal position of the femur with respect to the tibia as the flexion angle increase. The low point kinematics show an anterior movement during flexion. These two trends are in accordance with the screw-home mechanism. Moreover, the low point show (figure 2) a typical medial pivot during flexion.

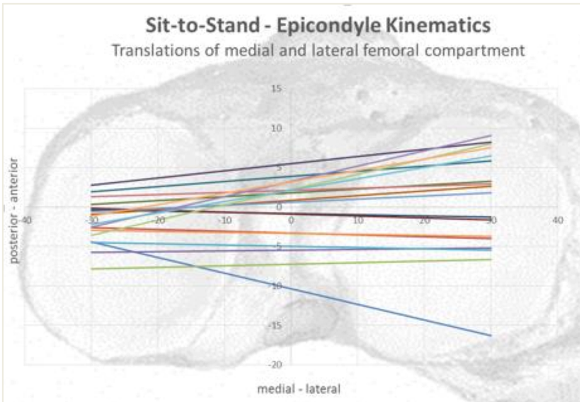

Figure 2: compartment motion of the low point kinematics.

CONCLUSIONS

The pre- and post- operative clinical scores shows an excellent satisfaction of the patients after 9 month. The data highlight the particular kinematic of the this model of prosthesis.
These results show that the ZIMMER PERSONA™ prosthesis restore a correct kinematics of the joint.
Further studies will focus the attention on different stress conditions to highlight possible hidden instabilities and to compare the prosthesis kinematic with a healthy knee, in order to study differences and performances.

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3. Clary CW et al., *J Biomech*, 46:1351-1357, 201

DAY 1

KEYNOTE 2- Prof Maiken Stilling

THE DEVELOPMENT OF AUTORSA INCLUDING DYNAMIC RSA AND THE FUTURE

Maiken Stilling[1,2,3]

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Aseptic loosening is the most common failure mechanism of orthopedic implants. Radiostereometric analysis (RSA) is the gold standard method for assessment of fixation of joint arthroplasty, and has been used as a research tool for more than 45 years in randomized trials to evaluate early (2 year) implant fixation as a proxy-measure for long-term implant fixation. RSA is a recommended EU standard and FDA prerequisite in the initial phase for stepwise clinical introduction and quality-assurance of new orthopedic implants presented to the free market.

Dynamic radiostereometric analysis is a high-frequency synchronized image recording of a joint motion during activity, which can be used to quantify joint kinematics. Subject specific bone models may be segmented from CT scans and used with model-based RSA for preoperative assessment. However, the use of bone models add yet another technical step to the existing manual user-intensive and quite time-consuming commercially available RSA analysis software methods.

AutoRSA is a technological research project initiated at Aarhus University Hospital in 2014, which mission to transform RSA from a research tool into an automated and clinically integrated image-diagnostic platform. The main goals were:

1) to build a continuous RSA database and monitor fixation of all hip- and knee implants
2) to establish acceptable implant migration limits over time (static RSA) with concurrent evaluation of patient reported outcome measures and revisions
3) to develop dynamic RSA software for non-invasive functional assessment of stability and kinematics in native and prosthetic joints and validate the use of it
4) to improve dynamic RSA technology, optimize calibration, and assess RSA quality between hospitals

During the AutoRSA project we have established a quality-assurance RSA database, which currently includes approximately 2000 consecutive hip and knee arthroplasty patients. These patients will be followed in the future for assessment of patient factors associated with implant failure, and to establish migration limits over time for different implant types.

We developed a fast marker-free analysis method for dynamic RSA that use subject specific CT bone models created with automated segmentations or implant CAD models (AutoRSA software). Precision is validated to be equal or better compared to traditional marker-based RSA.

We performed a number of cadaver studies and validated dynamic RSA for evaluation of kinematics in hip, knee, elbow and forearm/wrist. We evaluated midterm inducible displacement and function of unicondylar knee arthroplasty during daily activities such as stairclimbing (Figure 1) and bicycling.

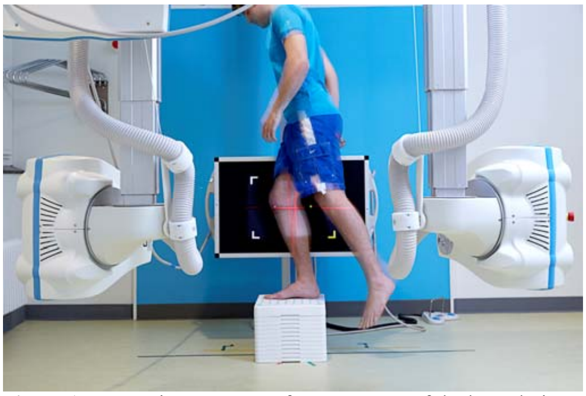

Figure 1: Dynamic RSA set-up for assessment of the knee during a step-up motion (AdoraRSA, Nordic X-ray Technique, Denmark).

Several clinical projects using dynamic RSA are currently in progress. We will continue to validate clinical use of dynamic RSA for precise patient-specific non-invasive kinematic evaluations of stability and function in native and arthroplasty joints.

We also optimized the radiological technology for dynamic RSA and developed calibration cages with improved precision. Further, we constructed a highly accurate phantom for assessment of RSA precision between hospitals that use RSA. The phantom may be used as a quality assessment of RSA sites in the future.

We look forward to share the results of the AutoRSA project at the 5th RSA Conference in Adelaide, and in the years to come.

DAY 1

PODIUM 2 – Joint Session

FLUOROSCOPIC ANALYSIS OF TWO TKP SYSTEMS DURING STEP-UP AND LUNGE MOTIONS

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INTRODUCTION

Approximately 50% of failing Total Knee Prostheses (TKP) fail due to sub-optimal biomechanical position and functioning of the prosthesis [1] and about 20% of patients with a TKP remain unsatisfied after surgery mainly due to suboptimal restoration of joint mechanics [2]. Prosthesis design changes should therefore focus to improve biomechanics and function of the TKP. This study investigated the non-inferiority principle of a new TKP with its established predecessor on joint functionality by means of fluoroscopy. Does the new TKP has a similar or larger in-vivo anterior-posterior (AP) displacement of the contact points between the femoral and tibial components and a similar or larger knee flexion angle range during step-up and lunge motions? Is there a relation between fluoroscopic results with RSA migration results and Patient Reported Outcome Measures (PROMs) one year post-operatively?

DESIGN / METHODOLOGY

15 patients with a NexGen TKP and 15 patients with a Persona TKP, both cemented, Posterior Stabilized and fixed bearing (Zimmer, Warsaw, Indiana USA), who were part of a larger RCT investigating the NexGen and Persona TKP, were invited for fluoroscopic acquisition 1 year post-operatively. Patients performed a step-up motion using an 18 cm high platform and an active, unsupported, maximum lunge motion from the platform. Motions were recorded with a plat panel fluoroscope (10 Hz, Ultimax, Toshiba, Zoetermeer, the Netherlands). With Model-based RSA software (version 4.11 RSA*core*, Dept. of Orthopaedics, LUMC, the Netherlands) the positions and orientations of the femoral and tibial components were determined. Using these positions and orientations the contact points and the knee flexion angels were calculated. Prosthesis migration measured by RSA and PROMs were recorded for all patients in the RCT.

Upon completion of data collection and analysis (August 2017) statistics will be performed to test for non-inferiority in AP contact point shifts and on knee flexion angles during step-up and lunge motions.

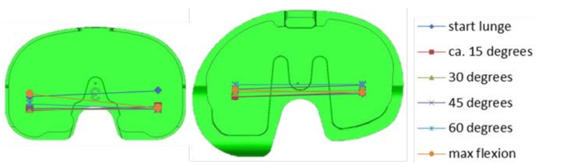

Figure 2: Contact point locations in a NexGen (Left) and a Persona (Right) right-sided TKP during lunge motion at different flexion angles (0 degrees is full knee extension).

RESULTS AND DISCUSSION

The Persona TKP is designed to increase the AP contact points shift and the knee flexion angles in order to better restore knee kinematics.

Figure 1 (lunge) and Figure 2 (step-up) show examples of AP shifts of the contact points at different knee flexion angles for a NexGen and a Persona TKP. The contact points in the patient with the NexGen TKP are more posteriorly positioned on the tibial component and the range of the contact point AP shift is larger compared to the Persona TKP. Lunge and step-up AP shifts ranges of the NexGen TKP are 6.3mm (14.8% of tibia component AP size) and 7.5mm (17.5%). For the patient with the Persona TKP these values are 4.4mm (8.2%) and 5.1mm (9.4%). Maximum active flexion angles obtained during the lunge motion for these two TKPs were 79.6 degrees (NexGen) and 71.9 degrees (Persona). Note that these values are based on single patient measurements and not representative for the prosthesis.

The platform height used in this study was selected based on the guidelines for step height in house construction in the Netherlands. The lunge motion in this study was the maximum achievable active flexion and could be taken as a motion that mimics lowering oneself on a chair or toilet. The height of the step-up motion or the depth of the lunge motion performed in this study might not have been sufficient enough to assess the full in-vivo functional possibility of both TKPs, however they are representative for two important movements in daily life.

CONCLUSIONS

Upon analysis of all fluoroscopic data conclusions can be drawn about the non-inferiority of the new Persona TKP with respect to the established NexGen TKP and the results of the two TKPs will be related to RSA migration data and PROM data and presented at the conference.

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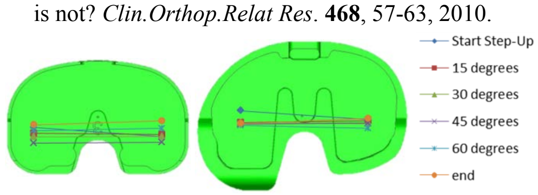

Figure 1: Contact point locations in a NexGen (Left) and a Persona (Right) right-sided TKP during step-up at different extension angles (0 degrees is start position: flexed knee).

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IN VITRO REAL-TIME MEASUREMENT OF FEMORAL MECHANICS DURING ACTIVITY

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INTRODUCTION

The human femur is subjected daily to complex three-dimensional and time-varying loads [1], likely leading to a loading-rate dependent viscoelastic femur response [2]. Nevertheless, in vitro measurements of femoral mechanics are often based on simplified quasi-static loading cases [3], which may not well represent typical daily scenarios. The Aim of this study was to measure the in vitro hip force, displacement and cortical strain in human femurs while replicating loading patterns of normal activity at varying loading rates from quasi-static up to real-time.

METHODS

Eight femurs from healthy elderly white women (body height, weight and age at death: 142 − 170 cm, 32 − 136 kg, 56 − 91 years) were obtained from a dedicated body donation program (Science Care, Phoenix, USA). The femoral diaphysis was cut at 180 mm from the proximal femoral head and potted 55 mm deep in aluminum cups using dental cement. Ten rosette strain gauges were attached to the bone surface at three femoral levels, 2 – 4 locations per level each positioned in the frontal, lateral, posterior or medial femoral aspect. Tests were conducted using a custom-built hexapod robot [4] capable of controlling the position of the top plate with a linear measurement error of ± 10 µm. Forces and moments at the femoral head center were measured by a six axis load cell (ATI, Apex, USA). The specimen was mounted on the base frame using a custom made fixation system. Bone moisture was maintained throughout the experiment using fabric tissue soaked with phosphate-buffered saline solution. The hip contact force during normal walking, stair ascent, stair descent, stumbling, rising from and sitting on a chair was taken from a public database (http://orthoload.com, [1]). The average force profile was scaled to the 75% of the donor’s body weight to ensure no permanent damage was caused to the specimen and applied to the femoral head through the polyethylene acetabular socket by actuating the top plate. One to three pre-conditioning cycles consisting of a sinusoidal cranio-caudal force (amplitude: 300 N, frequency: 0.1 Hz) were used. An adaptive velocity-based load control algorithm was used to apply the hip contact force to the specimen using 50 intermediate frames over each loading cycle. Ten seconds were used to ensure the algorithm converged at each frame. The position of the top plate was recorded and played back by multiplying the cycle time length by a factor 20 (quasi-static), 5, 2 and 1 (real-time). Strains were recorded at 2 kHz using a modular data logger (National Instrument Corporation, Austin, USA) and a 0.5 V excitation to prevent cortex heating. The error across activities was calculated. The hip force time history expressed as percentage of the walking cycle. The hip force was normalized by the peak force measured during the quasi-static trial (F20x) to assess changes of femoral stiffness with loading rate. The analysis of cortical strain is in progress.

RESULTS AND DISCUSSION

The protocol successfully replicated in vitro the three-dimensional hip force during normal activity. The error of the hip force time history was 3.3 ± 14.7 N and -0.7 ± 1.6 Nm across activities using the load-control approach while the difference between the quasi-static and the load-control simulation was 9 ± 10 N. The femoral stiffness was activity and loading-rate dependent; the normalized force ranged from 1.1 during stair ascent to 1.35 during walking (Figure 1) where the peak force varied from 556 N (quasi-static) to 749 N (real-time).

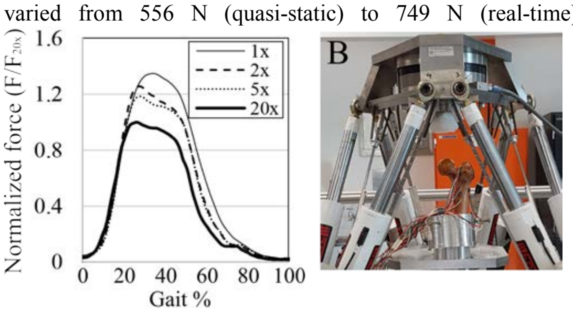

Figure 1: The normalized force at the hip for different loading rates during walking (A) and one representative femoral specimen mounted in the hexapod robot (B).

CONCLUSIONS

The stiffness of the human femur is loading-rate and activity dependent. The present protocol can be used to study the mechanics of entire bones subjected to complex three-dimensional dynamic loads. The analysis of cortical strain may help elucidate the relationship between femur stiffness and strain rate. This information is important for studying the femur mechanics during normal activity.

ACKNOWLEDGEMENTS

Australian Research Council (DE140101530).

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Dynamic radiostereometric analysis for evaluation of hip joint pathomechanics

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INTRODUCTION

Dynamic RSA (dRSA) enables precise non-invasive 3D motion-tracking of bones[1–3]. The development of non-invasive model based analysis methods allows for preoperative evaluation of in-vivo hip joint kinematics including hip pathomechanics such as femoroacetabular impingement (FAI) and the biomechanical effects of arthroscopic cheilectomy and –rim trimming (ACH).

The aim of this study was to establish methods for evaluation of hip-joint kinematics before and after ACH.

METHODS

Seven non-FAI affected human cadaveric hips were CT-scanned and CT-bone models were created. dRSA recordings of the hip joints were acquired at 5 frames/sec during flexion to 90°, adduction to stop and internal rotation to stop (FADIR). ACH was performed and dRSA was repeated. dRSA images were analyzed using model-based RSA[4]. Hip joint kinematics before and after ACH were compared pairwise. The volume of removed bone was quantified and compared to postoperative range of motion (ROM).

RESULTS AND DISCUSSION

Mean hip internal rotation increased from 19.1° to 21.9° (p=0.04, Δ2.8°, CI:0.3°;5.3°) after ACH surgery. Mean adduction of 3.9° before and 2.7° after ACH surgery was unchanged (p=0.48, Δ-1.2° CI: -2.8°; 5.2°). Mean flexion angles during dRSA tests were 82.4° before and 80.8° after ACH surgery, which was similar (p=0.18, Δ-1.6°, CI: -4.1°; 0.9°). No correlation between the volume of removed bone and ROM was observed.

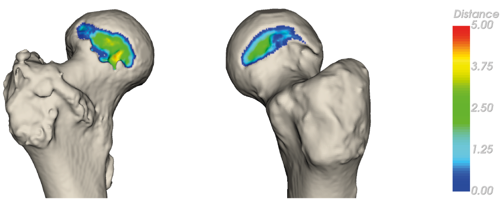

Figure 1: Postoperative CT-bone models imaging the resected bone areas. The color scale indicates the depth (mm).

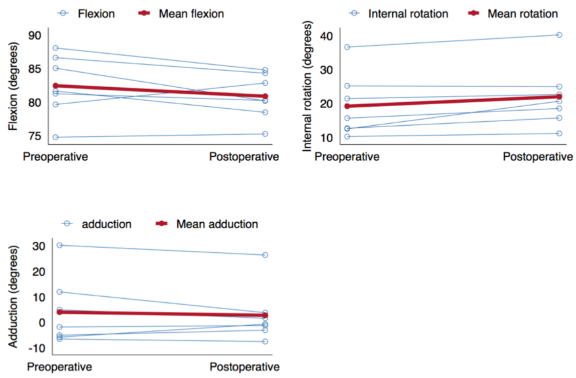

Figure 2: Scatter plot showing the development in flexion, internal rotation and adduction between the pre- and postoperative dRSA investigations (Red line: mean development).

CONCLUSIONS

A small increase in internal rotation, but not in adduction, was observed after arthroscopic cheilectomy and –rim trimming in cadaver hips. The hip flexion angle of the FADIR test was reproducible. dRSA kinematic model based analysis is a new and clinically applicable method with good potential to evaluate hip joint kinematics and good potential for testing FAI pathomechanics and other surgical corrections.

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SUBJECT-SPECIFIC KNEE KINEMATICS DURING WALKING IN CHILDREN AND ADOLESCENTS WITH RECURRENT PATELLAR DISLOCATION

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INTRODUCTION

Patellar dislocation (PD) is a relatively common injury in the skeletally immature population, with an estimated incidence rate of 43-77 per 100,000 individuals in children [1] and adolescents [2]. Furthermore, 38.4%-91% of children and adolescents experience recurrent patellar instability after acute first-time dislocation [3].

Patellar dislocation depends on multiple factors, including bone morphology, bone alignment, and soft tissue restraints. It usually occurs during dynamic tasks, due to the interplay among these elements. Recent studies on a mixed population of adolescents and adults with patellar instability [4] revealed gait pattern deficits, such as smaller tibiofemoral joint (TFJ) flexion excursion. Therefore, analysing the TFJ can provide insights on the stability of the patellofemoral joint (PFJ). Nevertheless, previous studies used link segment models with a simplified knee hinge joint, which cannot provide subject-specific three-dimensional TFJ kinematics. Subject-specific TFJ kinematic models can account for the substantial inter-subject variability typical of the paediatric population with patellar instability.

The aim of this study was to investigate the TFJ kinematics during gait of children and adolescents suffering from recurrent PD by using subject-specific TFJ kinematic models.

METHODS

Four patients (age: 11.7±2.1, mass: 56.3±12.2 kg, height: 1.60±0.08 m) who presented with recurrent PD and 4 age-matched control participants (age: 11.0±2.5, mass: 35.0±9.1 kg, height: 1.52±0.19 m) underwent MRI (full lower limb and high resolution knee scans) and 3D gait analysis. A 10-camera Vicon system (Vicon Motion Systems Ltd, UK) recorded 3D marker positions during 6 walking trials. For each participant, 3D lower limb bones, knee ligamentous and cartilage structures were reconstructed using Mimics 19.0 (Materialise, Leuven). Sulcus angle and tibia tuberosity to trochlear groove (TT-TG) distance were measured to appreciate if PFJ morphology influences TFJ kinematics. The TFJ was modelled in OpenSim, based on optimized MRI-measured geometrical parameters [5], as a 5-rigid-link parallel mechanism including surface contact conditions and three knee ligaments (ACL, PCL and MCL). Joint angles were calculated by tracking experimental markers while minimizing ligament elongation [6] using the least squares multibody optimization tool available in OpenSim.

RESULTS AND DISCUSSION

PD patients exhibited high sulcus angle (158.5±12.2°), high TT-TG distances (19.2±5.7 mm) and a more externally rotated tibia during gait (Fig1B) with respect to controls, producing the likely poor intrinsic PFJ stability. To preserve PFJ stability, PD patients walked with a more flexed knee in midstance compared to controls (Fig1A), thereby avoiding high knee extension angles where the PFJ is susceptible to instability due to its incongruence in the femoral groove.

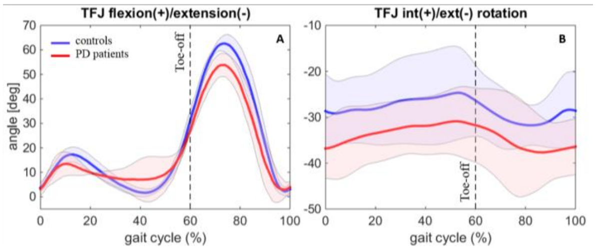

Figure 1: Average TFJ kinematics for PD patients and control participants during gait.

The average relative ligament elongation ranges obtained from the models (ACL: 2.53±0.90%, PCL :2.30±1.10%, MCL: 1.71±0.92%) were close to the experimental values (ACL: 2.72%, PCL: 3.73%, MCL: 0.44%) [7].

CONCLUSIONS

Three-dimensional subject-specific TFJ and PFJ kinematic models with individualized anatomical features are promising tools to investigate the pathological gait biomechanics of PD patients, and help in designing better surgical corrections.

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KINEMATIC COMARISON OF PRE- AND POST- ACL RECONSTRUCTION DURING SINGLE-LEG-SQUAT USING DYNAMIC RSA

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INTRODUCTION

The purpose of this work is to compare the kinematics of a cohort of patients with complete and isolated injury of the Anterior Cruciate Ligament (ACL) and the same patients reconstructed using two different surgical techniques.

The injured knee was evaluated using dynamic RSA the day before surgery (PRE) and then were re-evaluated after 4 months of follow up. The ACL were reconstructed using the "Double Bundle" (DB), or the "Single Bundle with Lateral Plastic" (SBLP) techniques [1]. The patients were asked to perform a single leg squat using the injured leg during dynamic RSA.

METHODS

A cohort of 42 patients with isolated and complete rupture of the ACL were recruited. The mean age was 28.75 (16-50) years old. The patients were evaluated using the using the dynamic RSA device (BiSTAND DRX, ASSING Group, Rome, Italy) before surgery. After 4 month follow up the patients were asked to repeat the dynamic RSA evaluation. They were asked to perform a single leg squat using the injured leg: from standing to maximal allowed flexion, to sanding. They were asked to perform the motor task according to their possibilities.

The kinematic was analyzed using custom dedicated software. The motion parameters were evaluated using the Grood and Suntay [1, 2] decomposition and the Low-point kinematics [3]. The time was normalized in percentage (0% begin, 50% maximal flexion, 100% end of the motor tasks). Then the averages of the PRE and of the DB and SBLP were evaluated and compared.

RESULTS AND DISCUSSION

The comparison of the pre-operative average data with the follow ups show significant differences and it is possible to distinguish between the two surgical techniques.

As shown in figure 1, the internal/external rotations have great differences between the data. The DB shows a significant difference in the path of stand-to-flexion with respect to return. The two lines are, in fact, very different. The SBLP is much different from PRE and DB.

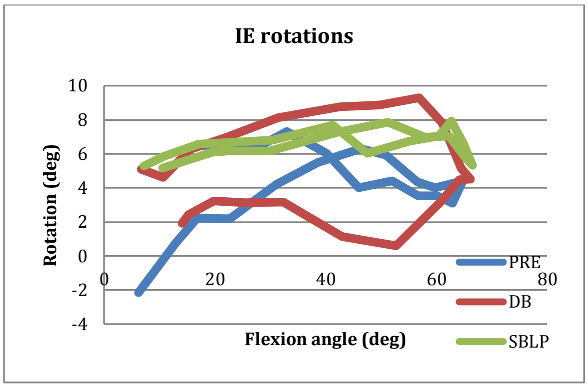

Figure 1: Internal/external rotations of the tibia during the single leg squat as a function of the flexion angle.

Also, the low point evaluations of the lateral and medial compartments, not shown here, have significant differences between PRE and follow ups, and it is also possible to distinguish the two surgical techniques.

CONCLUSIONS

The study of the ACL injured and reconstructed knees show that dynamic RSA is able to evaluate the differences between different surgical techniques and preoperative data with a motor task very difficult to analyze [5]. A comparison with non-pathological knee kinematics should be appropriated to analyze the effectiveness of the reconstruction surgery. Thus, the dynamic RSA showed to be a powerful technique to accurately analyze the knee motion both with prosthesis and bones.

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ELBOW BIOMECHANINCS, RADIOCAPITELLAR JOINT PRESSURE, AND INTEROSSOUS MEMBRANE STRAIN BEFORE AND AFTER RADIAL HEAD ARTHROPLASTY

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INTRODUCTION

Radial head fractures are common injuries and in cases with a complex fracture of the radial head and associated elbow instability a radial head implant (RHA) is indicated for surgical treatment. Good clinical results have been described however the revision and complication rate reported in the literature is concerning[1,2].

We hypothesized that the biomechanical properties would be restored, that the pressure in the radiocapitellar joint (RCJ) and the strain in the interosseous membrane (IOM) would remain the same after insertion of a RHA.

METHODS

8 human native elbows with a mean age of 82 years (range 61-89) were recorded with dynamic radiostereometric analysis (dRSA) during a flexion motion of the elbow in a motorized fixture with the forearm in 3 positions; neutral, supination, pronation, and in addition with supination and pronation with 10N varus load and valgus load respectively. Specimens were recorded at 10Hz with the digital AdoraRSA suite (NRT, Denmark) using a 20°-20° vertical tube position, Canon CXDI-50RF detectors, and a uniplanar carbon calibration box. Subject specific bone models of the humerus, radius, and ulna were created from CT scans using an automated method. Model-based RSA (RSAcore, The Netherlands) was used for calibration and initialization of the bone models on the first frame of the dRSA series, and further analyses were conducted using non-commercial AutoRSA software. Standardised anatomical axes and coordinate systems of the forearm were used. Translations of the radial head in the x-, y- and z-directions relative to the humerus and ulna were measured and kinematics were calculated. The contact pressure in the RCJ was measured using a thin-film pressure sensor (Tekscan) and the tension within the IOM was measured using a custom-made strain gauge. The experiment was repeated after insertion of an anatomical RHA (Acumed).

RESULTS AND DISCUSSION

After insertion of RHA the radial head was displaced mean 1.8mm medially and 1.4mm distally. During unloaded flexion motion the mean difference in translation between the native radial head and the RHA was less than 1mm (CI95 +/- 0.5mm) (p=0.00) (Figure 1), and with loading the difference was less than 1.5mm (CI95% +/- 1.5mm) (p=0.00). The mean difference in RCJ contact pressure between the native elbows and the RHA elbows was less than 0.30 MPa (CI95% ± 0.40 MPa) (p=0.00) during unloaded flexion motion with the forearm in neutral, pronation and supination. After loading in supination, the difference in RCJ pressure was mean 0.58 MPa (CI95% ± 0.40 MPa) (p=0.00) and max 2.15 MPa. The tension in the IOM in supinated (p=0.03) and pronated (p=0.00) forearm position was higher for the RHA elbows but when applying varus-valgus stress in supinated (p=0.00) and pronated (p=0.00) forearm position the tension decreased in the RHA elbows.

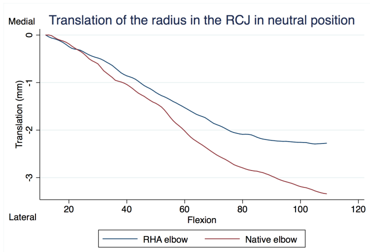

Figure 1: Example of increase in radius translation in the RCJ with increasing elbow flexion after insertion of the RHA. The neutral unloaded elbow position is shown.

CONCLUSIONS

There were only submillimeter kinematic changes and small joint pressure increases in the RCJ after optimal insertion of an anatomical RHA in an experimental setting. Likewise, the changes of pressure in the RCJ and the strain changes in the IOM were small and expectedly not of any clinical significant relevance. These results are promising for the use of Acumed anatomical RHA.

ACKNOWLEDGEMENTS

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   Acumed provided the implants and sponsored the rental of equipment to measure joint pressure but had no influence on the data handling or interpretation of results. We received a grant from the Innovation Fund Denmark (grant# 69-2013-1), a public fund, and a grant from the Aarhus University Research Fund as payment to the medical student who conducted the study.

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Changes in objectively measured activity in patients following total hip arthroplasty

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INTRODUCTION

Total hip arthroplasty (THA) is a successful procedure for patients with end-stage osteoarthritis, attributed to significant improvements in pain and self-reported function. However, measures of function using questionnaires may not be an accurate reflection of actual daily activity as part of physical functioning. Accelerometers can be used as a more advanced method to identify accelerations in three directions (vertical, anteroposterior, and mediolateral and accurately discriminate between sedentary and physical activity time [1]. Previous research has used an accelerometer to evaluate activity following THA [2], however the accelerometer was only worn for two consecutive days, which may not be a true reflection of the day to day activities an individual may perform over one week.

The aim of this study was to measure the total amount of activity and sedentary time in end-stage OA patients before surgery and following THA. We aimed to determine the effect of THA on patients' actual activity to identify if objective measure of function is reflective of the self-reported improvements in pain and function using the WOMAC

METHODS

Patients wore a GeneActiv, wrist-worn accelerometer [3] at four time points: before surgery (four-seven days), immediately after surgery (2-week duration), 6 weeks (one week duration), and 3 months (one week duration) after surgery. Total activity (TA) was defined as the average sum of light, moderate, and vigorous activity.

Following discharge from hospital, patients were not instructed to undergo additional rehabilitation from the normal advice at the Royal Adelaide Hospital. Patients were excluded from the study if they were wheelchair bound or used the aid of a four-wheel walker to mobilise. Patients with diagnosed musculoskeletal condition in another joint were also excluded from the analysis.

RESULTS AND DISCUSSION

Prior to surgery, patients were active for 3.8 hours ± 1.4, whilst spending 12.5 hours (h) ± 3.42 in sedentary time (S). Following surgery, a reduction in activity and increase in sedentary time was seen in the first 2 weeks (TA = 2 ± 2.2 h; S = 13.6 ± 2.2 h, $P = < 0.05$). No significant difference to pre-op activity was observed at 6 weeks (TA = 2.8 ± 1.5 h; S = 12.6 ± 2.2 h) and 3 months, post-surgery (TA = 3.9 ± 0.6 h; S = 11.4 ± 1.3) (Figure 1). Despite patient's demonstrating no change in activity and sedentary time at 3 months compared to pre-operative function, patients reported a significant reduction in pain and increase in self-reported function using the WOMAC questionnaire ($P = 0.0005$).

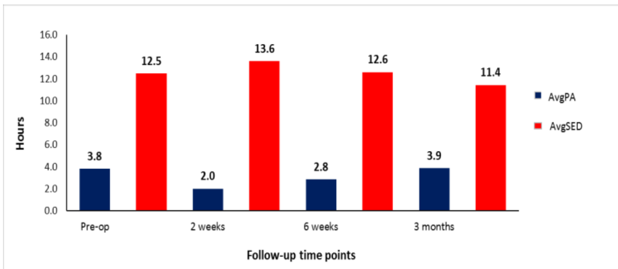

Figure 1: Total time (hours) spent in activity and sedentary time pre-operatively and at three time points following THA.

CONCLUSIONS

This finding suggests self-reported improvements in pain and function are not reflective of actual daily activity with patients demonstrating no change in total activity or sedentary time at 3 months post-THA despite reporting significant improvements in pain and self-reported function.

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NIL

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DYNAMIC RADIOSTEREOMETRIC ANALYSIS FOR EVALUATION OF KINEMATICS IN THE DISTAL RADIOULNAR JOINT BEFORE AND AFTER TFCC LESIONS

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INTRODUCTION

The Triangular Fibrocartilage Complex (TFCC) is the main stabilizer of the distal radio ulnar joint (DRUJ) [1]. Traumatic injuries of the TFCC can lead to dynamic DRUJ instability and restricted hand function. Altered kinematics and joint translation due to DRUJ instability is difficult to grade by clinical and with current radiological examinations.

Wrist arthroscopy is the gold standard for diagnosing TFCC ligament injuries and can differentiate proximal (*pc*) and distal component (*dc*) TFCC lesions [2]. Dynamic radiostereometry (dRSA) may record functional joint instability precisely and potentially be used to grade and diagnose DRUJ instability[3]. We hypothesized less DRUJ stability after cutting the *dc*-TFCC and *pc*-TFCC in comparison with the intact TFCC.

METHODS

Ten human donor arms (8 men), with a mean age of 78 years (range 63-90) were evaluated. Subject specific bone models of the radius and ulna were created from CT scans using an automated method. A motorized fixture that simulated in vivo DRUJ movements was developed and used to examine forearm movements between 40° radial and 30° ulnar deviation with neutral wrist extension in a standardised setting. Specimens were recorded at 10Hz with the digital AdoraRSA suite (NRT, Denmark) using a 20°-20°tube position, Canon CXDI-50RF detectors, and a uniplanar carbon calibration box. Ligament lesion intervention on first the dc-TFCC at the ulnar styloid insertion and later the pc-TFCC on the ulnar fovea insertion was done with fluoroscopic visualization. dRSA and arthroscopy (for ligament lesion verification) was repeated after each intervention. Model-based RSA (RSAcore, The Netherlands) was used for calibration and initialization of the ulna and radius bone models on the first frame of the dRSA series [3], and further analyses were conducted using non-commercial AutoRSA software. Kinematics of the forearm was described using standardised anatomical axes and coordinate systems (fig. 1).

RESULTS AND DISCUSSION

DRUJ gapping and ulnar variance was smaller in ulnar wrist deviation compared with radial wrist deviation for the intact TFCC ($p<0.01$), and lesion of the *dc*-TFCC and *pc*-TFCC did not change this ($p>0.07$). During radial to ulnar wrist deviation the DRUJ translation was mean 0.83 mm (CI95 0.57-1.09) with intact TFCC, which corresponds to a DRUJ translation of 6.0 (CI95 4.0-8.0) percent points from min. 47.7% (CI95 40.2-55.3) to max. 53.7% (CI95 46.8-60.6) of the sigmoid notch size. Intervention with *dc*-TFCC lesion had a DRUJ translation similar to intact TFCC with mean 8.3 (CI95 5.3-11.4) percent points ($p=0.10$), while combined *dc*-TFCC/*pc*-TFCC lesion increased DRUJ translation to mean 9.6 (CI95 7.0-12.3) percent points ($p=0.02$).

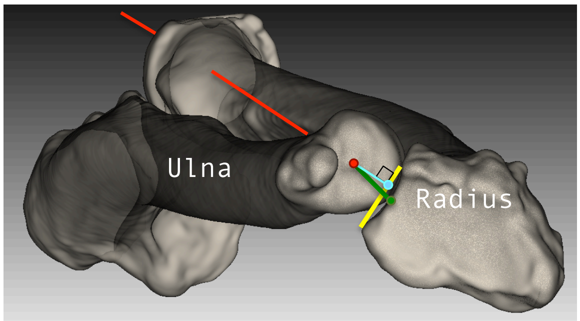

Figure 1: *DRUJ gapping* (green line) was measured from the center of the ulnar head to the center of the radius sigmoid notch, *ulnar variance* was the change in radius length on the kinematic length axis of the forearm (red line) and *DRUJ translation* was measured as the change in interception point (turquoise) from the kinematic length axis perpendicular on the radius sigmoid notch line (yellow).

CONCLUSIONS

DRUJ kinematics showed a decrease in ulnar variance and DRUJ gapping during radial to ulnar wrist deviation, which was similar for the intact TFCC and the cut TFCC ligaments. The translation of the radius with respect to the ulna increased with *dc*-TFCC lesion and reached statistical significance with a combined dc-TFCC/*pc*-TFCC lesion.

Arthroscopy provides a subjective evaluation of TFCC lesions and DRUJ instability. This is the first dRSA study of DRUJ stability. The dRSA method is non-invasive, low-dose, and clinically applicable and enables precise quantification of DRUJ instability. Further dRSA analyses are in progress and will be presented at the conference.

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CONFLICT OF INTEREST DECLARATION

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

If you have accepted any support such as funds or materials, tangible or intangible, concerned with the research by the commercial party such as companies or investors, choose YES below, and state the relation between you and the commercial party.

YES

1.We received a grant from the Innovation Fund Denmark (grant# 69-2013-1), a public fund.
2. We recieved a grant from the Aarhus University Research Fund as payment to the PhD student who conducted the study.

Do you have a conflict of interest to declare?

NONE

DAY 1

PARALLEL PODIUM 2 – ANZORS Session

RADIOGRAPHIC, MECHANICAL AND HISTOLOGICAL EVALUATION OF FUSION USING PEEK INTERBODY CAGES WITH AND WITHOUT A POROUS TITANIUM ALLOY COATING, IN AN OVINE MODEL

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INTRODUCTION

Polyetheretherketone (PEEK) is a common material for spinal interbody cages, and has an elastic modulus closer to bone than metal alloys [1], which may reduce graft stress shielding and endplate subsidence [2]. However, PEEK may not bond directly to bone whereas surface textured titanium and titanium alloy (Ti) implants can exhibit bony integration [3]. PEEK interbody cages incorporating titanium or titanium alloy surfaces may promote early fusion and improve spinal fusion rates. The aim of this study was to compare radiographic, mechanical and histological indices of fusion in an ovine model for: (A) PEEK interbody cages; and, (B) PEEK interbody cages with nano-surfaced porous Ti endplates (PEEK+Ti) (Nanovis LLC).

METHODS

14 skeletally mature Merino sheep (mean 69.6 kg) randomly received a PEEK or PEEK+Ti cage, with autologous bone graft, at L4/L5. Radiostereometric (RSA) assessments and CT scans were obtained at 0, 3, 6 and 12 mth post-surgery. Intervertebral flexion-extension range of motion (ROM) was determined using UmRSA (RSA Biomedical, Sweden). A linear mixed model (LMM), was used to determine if ROM was dependent on cage type or post-operative time point. On CT images, fusion was defined as the presence of ≥2 trabeculae passing between vertebral endplates in both the sagittal and coronal plane, and the absence of radiolucency around the cage. Comparison was made at each time point with a Fisher's exact test. Lumbar spines were excised at 12 mth and L4-5 vertebral bodies subjected to quasi-static low load mechanical testing in flexion-extension (FE), lateral bending (LB), axial rotation (AR), anterior shear (ASh) and compression. Stiffness and ROM were compared using Mann-Whitney U-tests. Centre sagittal histological sections were stained with Toluidine blue; fusion was defined as continuous bony bridging across the endplates, and assessed using a Fisher's exact test. α=0.05 for all tests.

RESULTS AND DISCUSSION

One animal died at 6 mth and was excluded from 12 mth outcomes. The median FE intervertebral angle was slightly lower for the PEEK+Ti cage at each time point, but the LMM revealed ROM was not statistically dependent on Cage Type (PEEK vs. PEEK+Ti), or Time (0, 3, 6, 12 mth). Most relative rotations were ≤4°. There was no significant difference between the CT-derived fusion rates at any time point. There was a trend for the PEEK+Ti group to have higher overall fusion rates at 3 (43 vs. 14%) and 6 mth (71 vs. 43%), higher central fusion rate at 3 mth (43 vs. 14%), and lower anterior fusion rate at 12 mth (29 vs. 67%), but these differences were not statistically significant. 43% of PEEK, and 29% of PEEK+Ti cages exhibited radiolucency at 3 mth; none was observed at 6 and 12 mth. There was no difference in stiffness or ROM between the PEEK and PEEK+Ti groups, for any loading direction (Table 1). Histology showed abundant trabecular bone inside the cage at 12 mth for all except one in the PEEK+Ti group. A cartilaginous inclusion between the superior and inferior bony ingrowth was noted in the centre of some cages. Overall fusion was present in 66% (4/6) PEEK, and 71% (5/7) PEEK+Ti, and central bridging bone was observed in 66% (4/6) PEEK, and 43% (4/7) PEEK+Ti; both statistically insignificant.

CONCLUSIONS

PEEK and PEEK+Ti cages achieved intervertebral fusion in this ovine model, with a non-significant tendency towards earlier fusion for PEEK+Ti. There was no significant difference in RSA, CT or histological measures of fusion, nor mechanical response, at 12 mth post-surgery.

ACKNOWLEDGEMENTS

C Jones: NHMRC Early Career Research Fellowship. Project funded in part by Nanovis LLC.

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Table 1. Stiffness [median (interquartile range)] for each direction of mechanical testing.

	FE (Nm/°)	LB (Nm/°)	AR (Nm/°)	ASh (N/mm)	Compression (N/mm)
PEEK	36.5 (11.9)	37.2 (8.0)	5.4 (3.8)	82.1 (11.2)	1510.0 (1013.7)
PEEK+Ti	34.7 (6.1)	36.9 (11.0)	2.3 (1.5)	76.8 (15.9)	1519.9 (350.2)

<u>CONFLICT OF INTEREST DECLARATION</u>

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

If you have accepted any support such as funds or materials, tangible or intangible, concerned with the research by the commercial party such as companies or investors, choose YES below, and state the relation between you and the commercial party.

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Do you have a conflict of interest to declare? (DELETE TEXT as appropriate)

Yes

Nanovis LLC provided the implants in-kind and contributed some (but not all) funding to the animal experiments for this project. They were not involved in the study design, execution, or interpretation of results.

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AN ARTICULATED, INSTRUMENTED NECK FOR A PARAMEDIC TRAINING MANNEQUIN: PROOF-OF-CONCEPT DESIGN AND TESTING

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INTRODUCTION

Neck immobilisation manoeuvres are performed by paramedics and emergency room clinicians when moving patients with suspected cervical spine injuries. These manoeuvres may mitigate further harm to the spinal column and spinal cord [1]. Existing paramedic training mannequins do not have realistic neck articulations and are not instrumented to provide the user with feedback regarding mannequin neck motion. The aim of this project was to design, manufacture, and test a proof-of-concept low-cost instrumented and articulated neck for an existing paramedic training mannequin.

METHODS

The neck comprised three custom 3D-printed ball-and-socket articulations and four "vertebrae" with intervertebral motion limiting tabs and spring attachment points. Extension springs provided passive intervertebral stiffness (Figure 1B). A Stewart-Gough platform arrangement of six linear slide potentiometers (Bourns, UK) was used to measure the position of the head with respect to the torso (Figure 1C). Aluminium adaptor plates and locking mechanisms were designed to interface the neck with existing attachment points without modification of the mannequin (Ultimate Hurt, Laerdal). To calculate head position from the six potentiometer outputs, forward kinematics were solved with a Newton-Raphson algorithm. A user interface provided real-time feedback and sampled data at 10 Hz.

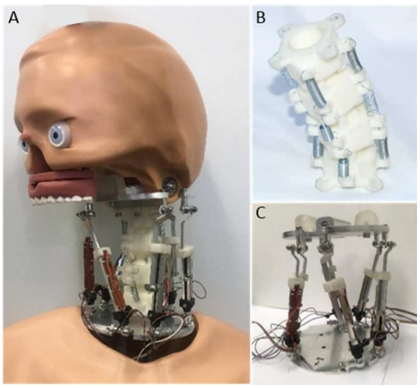

Figure 1: (A) Prototype installed in mannequin (jaw and head/neck "skin" removed); (B) "vertebral" elements with passive stiffness springs; (C) linear potentiometer assembly.

The accuracy of the measured angles was tested using a motion capture system (Optotrak Certus, Northern Digital). Markers were rigidly attached to the adaptor plates of the isolated neck and the upper plate was manually rotated about each anatomical axis for five cycles. The range of motion (ROM) about each anatomical axis [flexion (F), extension (E), lateral bending (LB), axial rotation (AR)] was measured in the same manner. Finally, full mannequin head- and shoulder-hold log-roll manoeuvres were performed by a trained paramedic and assistants to determine the head-to-torso rotations and translations likely to occur during use.

RESULTS AND DISCUSSION

The errors (root-mean-squared) associated with the measured rotation of the superior plate relative to the inferior plates were: F-E: 0.16°, LB: 0.27° and AR: 1.42°. The ROM were limited by the potentiometer assembly rather than the intervertebral tabs: F: 19.2°; E: 22.3°; LB: 21.7° (L), 21.4° (R); AR: 42.7° (L), 26.2° (R). The ROM were close to lower physiological limits for LB (22-45°) and AR (44-79°), but outside the limits for F (36-64°) and E (49-85°) [2,3]. The AR ROM asymmetry was due to the potentiometer push-rod arrangement. During the log-roll trials, the peak deviations from initial position were: F: 9.6°, E: 10.0°; LB: 11.5° (L), 11.8° (R); AR: 19.9° (L), 21.9° (R). This indicated that the neck ROM is likely adequate if the initial position is within ±5-10° of neutral in any direction.

CONCLUSIONS

The neck ROM approached a suitable level in LB and AR, but was limited in the F-E direction. It allowed accurate measurement of head rotation relative to the torso, and allowed motion within the envelope likely during immobilization manoeuvres in a close-to-neutral position. Improvements are required to increase ROM, particularly in the F-E direction.

ACKNOWLEDGEMENTS

C Jones is supported by an NHMRC Early Career Research Fellowship (APP1072387).

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BIOMECHANICAL INVESTIGATION OF A BRACED ARM-TO-THIGH LIFTING TECHNIQUE FOR OCCUPATIONAL TASKS, WITH KINEMATIC ANALYSIS AND COMPUTER MODELING APPROACHES

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INTRODUCTION

Low back pain (LBP) is a common and costly health condition that is related to occupation and activities of daily living [1, 2]. Despite the common use of one-handed lifting techniques for activities of daily living, they have received little attention in the biomechanics literature. The braced arm-to-thigh technique is a one-handed lifting method, in which the dominant hand picks up low-to-moderate mass objects, while the free hand braces the trunk on the corresponding thigh. This technique reduces compression forces in the lumbar spine of young healthy males, compared to unsupported lifting methods [3]. The specific aim of this study is to perform a biomechanical analysis of the braced arm-to-thigh lifting technique in 20 healthy and 20 LBP participants, and compare the results to two-handed or unsupported one-handed lifts. This abstract presents the data that has been collected to date for one male LBP participant.

METHODS

Three repetitions of four different lifting techniques with a load of 5 kg were performed by one male participant (age 30, body mass 81.9 kg): two-handed squat (2SQ), two-handed stoop (2ST), one-handed stoop (1ST), and braced. Kinematic and kinetic data were collected with a 12-camera Vicon motion analysis system (100Hz, Oxford Metric, UK) and two force platforms (2kHz, AMTI, USA). A three-axis load cell (2kHz, Kistler, SUI) secured to the thigh directly above the knee measured the bracing forces applied by the hand.

A modified version of the Raabe et al., [4] full body OpenSim model with a detailed lumbar spine, was used to determine the trunk angles, lumbar joint loads, and muscle activation for the different lifting techniques.

RESULTS AND DISCUSSION

The peak trunk flexion was lower for the braced technique (45°) than for the other three lifting techniques (1ST: 62°; 2ST: 60°; and, 2SQ: 52°).

The estimated compression and shear forces at L5/S1 were both reduced by the bracing force on the thigh. Compressive forces at L5/S1 were reduced by 12%, 15%, and 19%, while the shear forces were reduced by 57%, 58%, and 52%, when compared to the 1ST, 2ST, and 2SQ, respectively. Kingma et al. [3] observed similar compressive force reductions in healthy males. The peak resultant bracing force for the braced technique was 127 N, which is within the 110-218 N range reported by Kingma et al. [3] for a similar supported lifting technique.

The muscle activation for both the right and left erector spinae (ES) were reduced during the braced technique, when compared to the other techniques. ES forces were lower on the right; this participant applied the bracing force to the left thigh.

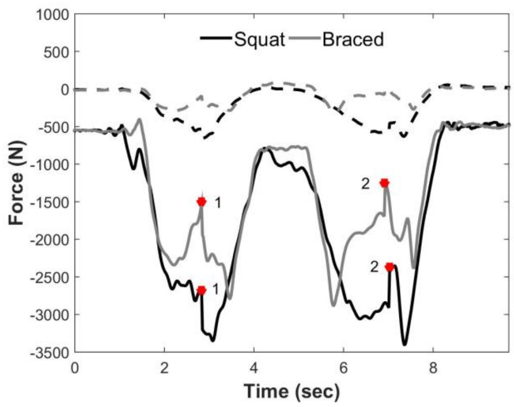

Figure 1: Compression forces (solid lines) and shear forces (dashed lines) at L5/S1 for 2SQ and braced lifts. Load pick-up (1) and put-down (2) are indicated by the filled circles.

CONCLUSIONS

Bracing the trunk, via the hand and arm, led to reduced lumbar spine loading and reduced ES muscle activations during lifting for this participant. The total trunk angle was reduced during braced lifting.

ACKNOWLEDGEMENTS

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OSSEOINTEGRATED IMPLANTS IN PATIENTS WITH PERIPHERAL VASCULAR DISEASE: A MULTI-CENTRE CASE SERIES WITH 1-YEAR FOLLOW-UP

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INTRODUCTION

Lower limb amputees are traditionally fitted with socket prostheses, but many continue to experience socket-interface problems such as discomfort and skin ulceration. Osseointegration is an alternative treatment that completely eliminates socket-interface problems, involving the direct insertion and incorporation of a titanium implant into the residual bone, which is percutaneously attached to a prosthetic limb through a small skin opening [1]. Although the majority of limb amputations are due to vascular disease, this has been an exclusion criterion for osseointegration surgery to date. For vascular patients who are unable to undergo other types of reconstruction, osseointegration surgery may have a substantial protective role against myocardial infarction or stroke following amputation by bringing functional restoration and mobility improvement. For the first time, this case series reports the outcomes of osseointegrated reconstruction in patients with limb amputation due to peripheral vascular disease, who were treated at two centres in Australia and the Netherlands.

METHODS

This is a multi-centre case series with 12-months post-operative follow-up in patients with unilateral trans-tibial amputation and a history of peripheral vascular disease, who received osseointegrated implants during 2014–2015. Due to failure to control the patients' underlying conditions, osseointegration surgery was performed to salvage the knee joint and/or allow the patients to improve their chances of maintaining a high mobility level post-operation. Osseointegration surgery, post-operative care and rehabilitation were conducted according to published protocols [1]. Clinical and functional outcomes were assessed including pain, prosthesis wearing time, mobility, walking ability, and quality of life. Adverse events were monitored and recorded, including infection, fractures, implant failure, revision surgery, further amputation and death. This study has been approved by the human research ethics committee and all participants provided their informed consent.

RESULTS AND DISCUSSION

Five trans-tibial amputees (aged 56–84 years) were included in this case series. At the 12-month post-operative follow-up, all patients were pain-free and demonstrated improved mobility. Notably, three of the five patients were wheelchair-bound prior to osseointegration surgery, but all were able to walk unaided and perform daily activities using the osseointegrated prosthesis at follow-up. Evidence of osseointegration between the bone and implant was observed in all patients (Figure 1). One patient experienced pain at the stoma site due to progressive peripheral vascular disease, which was treated successfully using balloon dilatation. Two patients had a single episode of superficial soft-tissue infection. No other adverse events were recorded. Considering that the 1-year mortality rate following amputation for patients with vascular disease reaches 48% [2], the osseointegrated prosthesis can provide such patients with immense benefits including improved function, mobility, quality of life, and even survival.

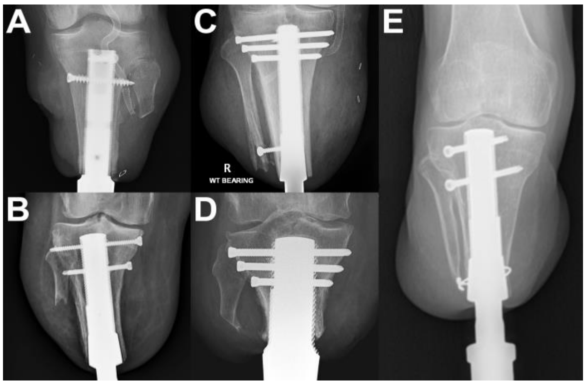

Figure 1: Representative radiographs of the operated limb containing the osseointegrated implant, taken at 12 months post-operation for the five patients.

CONCLUSIONS

An osseointegrated implant may be considered a feasible alternative to the socket prosthesis for rehabilitating amputees with peripheral vascular disease. Further evidence is required to confirm the possibility of implementing osseointegration surgery as the standard of care for these patients.

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ASSESSMENT OF HIP IMPLANT CONDITION THROUGH A COMBINED APPROACH OF ACOUSTIC EMISSION MONITORING AND PATIENT GAIT ANALYSIS

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INTRODUCTION

Early diagnosis of total hip arthroplasty (THA) implant deterioration may allow proactive surgical intervention and improve patient outcomes. Acoustic Emission (AE) monitoring of THA implants utilizes ultrasonic receivers to record implant vibrations during dynamic patient motion. These acoustic emissions can provide insight into implant failure modes and potentially be used as a diagnostic indicator for future patients.

AIMS AND OBJECTIVES

This study aims to provide increased insight into the *in-vivo* condition of THA implants and develop a diagnostic tool to supplement existing diagnostic methods. This study also seeks to provide new insight by including patient gait analysis to better understand the underlying mechanics of implant failures.

METHODS

Four ultrasonic sensors are utilized for *in-vivo* AE monitoring of 110 THA patients, to capture the implant vibrations emitted. Implants components retrieved during subsequent revision surgery are then manipulated *in-vitro,* both manually and by a robot. Ethical approval was obtained from the New Zealand Upper South A regional ethics committee (URA/10/11/075).

AE signal features (duration, peak amplitude, root-mean-squared amplitude, rise time, and peak frequency) are extracted from THA AE events. Principal component analysis (PCA) [1] is performed on the extracted signal features to reduce the representation of each AE event to two pseudo features or principal components. The reduction from five features to two allows the relationship between AE events to be expressed visually (Fig.1). In parallel, three inertial measurement units are used to record patient limb motions. These measurements are then linked to a simple lower-limb biomechanical model to approximate the joint articulation angles during AE monitoring.

RESULTS AND DISCUSSION

PCA has shown that differences in AE activity exist between different patient cohorts (Fig.1). It was observed from Fig.1 that particular AE events occurred more frequently for some of the cohorts than others. For example, the *loosening* and *wear* cohorts of Fig.1 had regions with a much higher concentration of events than the same regions of the other cohorts. Additionally, the *noise* cohort had a large region that was more populated than the same region for the other cohorts.

Patient gait analysis may provide additional insight into the underlying implant mechanics and help identify cohort specific AEs. Further data is required before meaningful conclusions can be drawn that relate AEs with stages of the gait cycle and associated implant loading.

CONCLUSIONS

Overall, THA implant failure is a complex problem that is not yet fully understood. Initial insight has been gained from patients to date, but recordings were not related to any joint tracking or gait analysis. Ongoing research is investigating if AEs occur at given points within the gait cycle, or whether they occur more randomly within the different phases of gait.

ACKNOWLEDGEMENTS

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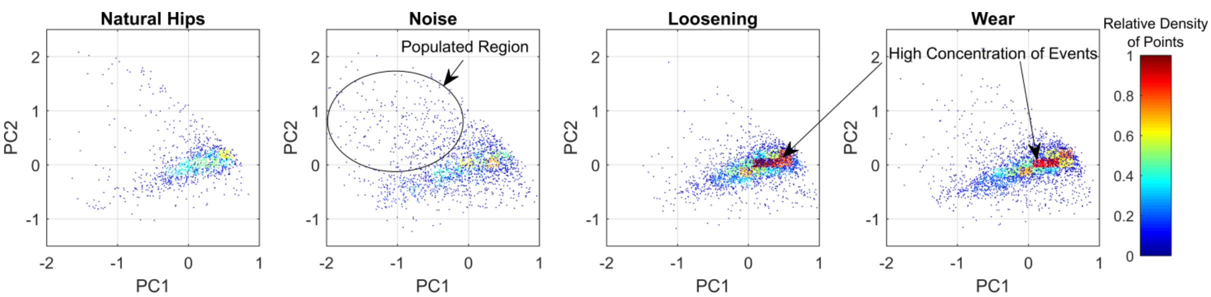

Figure 1: First and second principal components of AE events of different cohorts based on clinical outcomes.

TIME DEPENDENT LOSS OF TRABECULAR BONE PRIOR TO FIXATION IN THE FRACTURED TIBIAL PLATEAU.

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INTRODUCTION
In the setting of articular fractures, achieving adequate fracture reduction and fixation is integral for obtaining satisfactory long-term outcomes[1]. Prolonged time from injury to operative fixation can lead to increasing difficulty in achieving the desired reduction and fixation in these injuries[2]. The aim of the study was to assess the effect that time between injury and surgery had on proximal tibial cancellous bone in patients suffering a tibial plateau fracture, in terms of bone micro-architecture and expression of genes known to control bone remodelling.

METHODS
A prospective study of 29 patients admitted to the Royal Adelaide Hospital with tibial plateau fractures between 2014 and 2016 were included. During surgery, participants underwent cylindrical trabecular bone biopsy (diameter of 2.7mm, length 20-30mm) of the fractured and contralateral sides. Samples were examined by micro-computed tomography to obtain trabecular bone microarchitecture and real-time RT-PCR analysis for the expression of genes known to be involved in bone remodelling.
Relationships between morphometric parameters and time were examined using Pearson’s correlation analysis. Differences in morphometric parameters and gene expression between the injured and uninjured sides were examined using paired Student’s t-tests. Correlations were also examined between morphometric parameters and gene expression. A value for $p < 0.05$ was considered significant. Local ethics approval was obtained (approval number HREC/16/RAH/418).

RESULTS AND DISCUSSION
The trabecular bone volume to total volume fraction (%BV/TV, p=0.011), trabecular number (Tb.N, p=0.041) and trabecular thickness (Tb.Th, p=0.033) showed significant decreases in injured vs. control sides. Across the cohort, there were significant negative correlations found between both %BV/TV (r=-0.39) and Tb.Th (Fig 1, r=-0.54) in relation to time post injury in the injured limb that were not present for the control side. Both %BV/TV and Tb.Th showed significant negative correlations with the gene expression of tartrate resistant acid phosphatase (*ACP5*; *r=-0.56* r=-0.79) and the ratio of *RANKL*:*OPG* mRNA (*r=-0.64, r=-0.69*). A significant negative correlation was also found between Tb.Th and cathepsin K (*CTSK*; r=-0.57), These structure/gene expression correlations were not found in the contralateral (uninjured) leg of these patients.

CONCLUSIONS
Our study shows that there is a bilateral time dependent loss of cancellous bone in patients having sustained tibial plateau fractures, with a further loss of bone in the injured limb. This time dependent bone loss is associated with altered expression of genes that have been previously associated with bone remodelling, consistent with increased osteoclastic activity contributing to the loss of bone stock. Further studies are warranted to determine if this bone loss affects patient outcomes and the maintenance of the achieved operative fracture reduction.

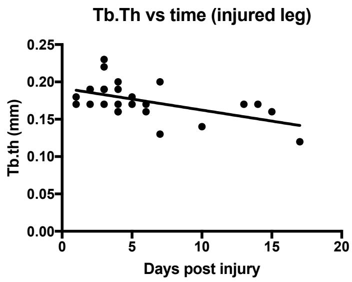

Fig 1. Relationship between Tb.Th and time post injury for the injured limb

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A PASSIVE ULTRASOUND PHASE-INTERFERENCE COMPENSATOR TO FACILITATE IMAGING OF SOFT-TISSUES THROUGH BONE

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INTRODUCTION

Transcranial ultrasound wave degradation created by variations in both thickness and tissue composition is a significant impediment to diagnostic imaging of the brain. The current 'active' solution is to vary the transmission delay of ultrasound pulses, inherently necessitating electronic control of each individual transducer element. By applying the sonic-ray concept of ultrasound wave propagation [1], it was hypothesised that wave degradation could be significantly reduced if both the transit-time and propagation path-length for all sonic-rays are made constant.

METHODS

With the aim of providing both spatial and temporal matching, the concept of a 'passive' physical ultrasound phase-interference compensator (UPIC), consisting of two layered materials of variable thickness, has been developed. Bespoke UPIC models were designed (layer 1 being 3D-printed Accura Bluestone, layer 2 being water) for a series of acrylic step-wedge test samples exhibiting varying degrees of ultrasound wave degradation associated with transit-time heterogeneity induced phase-interference.

RESULTS AND DISCUSSION

Time-domain analysis for a 20-step wedge sample is shown in Figure 1, showing significant phase-interference for the step-wedge sample alone, that is significantly reduced upon incorporation of the bespoke UPIC model.

Noting that the spatial resolution provided by the current 'active' approach is primarily determined by the physical size of the individual ultrasound transducer element(s), it is envisaged that the 'passive' UPIC approach will provide improved imaging performance, since it is primarily determined by the higher spatial resolution of 3D printers.

As with the current 'active' approach, a 3D clinical planning image (MRI or X-ray CT) would be required to facilitate the complex 3D-printed UPIC design solution; the ultimate aim being for this also to be provided by ultrasound.

It is further envisaged that the UPIC approach to provide high-fidelity ultrasound diagnostic images of soft tissues through bone will have clinical applications extending to orthopaedic surgery.

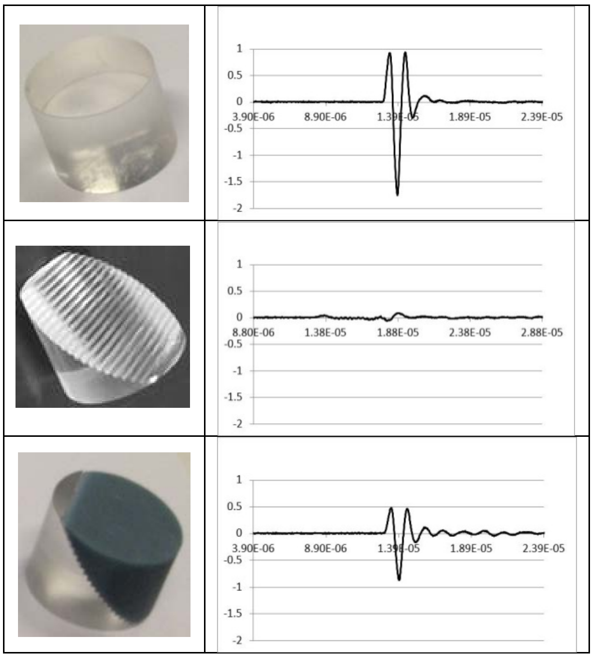

Figure 1: Left: photographs of solid acrylic sample plus 20-step wedge sample, without and with the bespoke twin-layer UPIC. Right: corresponding experimentally-derived ultrasound signals; axes are signal amplitude (volts) and time (seconds).

CONCLUSIONS

The concept of a passive twin-layer ultrasound phase-interference compensator (UPIC) has been introduced. Noting that the current experimental validation was performed on acrylic step-wedge samples, future work should consider diagnostic imaging through natural bone tissues such as the skull, distal femur and proximal tibia.

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DAY 1

PARALLEL PODIUM 2 – RSA Session

Radiostereometric Analysis Using Clinical Radiographic Views

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INTRODUCTION

Radiostereometric analysis (RSA) is an established powerful stereo imaging technique that delivers very accurate 3D measurements of musculoskeletal movement. Despite being developed over 40 years ago, it is still limited to use only as a clinical research tool rather than use in regular clinical practice. One limitation is the requirement RSA has for specialized radiographic views that differ significantly from that of routine clinical patient radiographs. We proposed a modified RSA technique that separates the conventional calibration procedure from the patient examination, enabling clinical radiographic views to be used for RSA measurements [1]. To link the numerous pairs of clinical views required for different arthroplasties, the development of a universal, orientation independent calibration object is essential.

METHODS

A Monte Carlo method was used to design the parameters of the new, universal calibration object, which included the object shape and size, the number of markers, and marker distribution pattern on the object [2]. Geometric calibration determines both intrinsic and extrinsic parameters of the RSA setting, and this determination was implemented in a Matlab environment. A knee joint phantom with 6 degrees-of-freedom was used to compare the accuracy and precision of the modified procedure, which uses the new calibration object, with that of conventional RSA using the traditional calibration cage. Femur to tibia relative movements driven by a composite positioning stage were examined by a pair of digital radiograph (DR) units. Afterwards, the knee calibration cage and the novel calibration object were examined. All captured radiographs were measured and the conventional RSA procedure was performed by UmRSA software. The modified RSA procedure was analyzed by an in-house Matlab code (due to the unique geometry) [2]. Accuracy, defined as average error, was calculated by comparing the measured movements with the true increments while precision was determined from the repeatability of double exposure measurements.

RESULTS AND DISCUSSION

The results from the validation study are shown in Tables 1 and 2. For the modified approach using the novel calibration object, the translational 3D accuracy was ±0.023 mm and its 3D precision was ±0.004 mm. Although statistical differences were present between certain measurements from the modified procedure and the conventional method, the differences were considered to be not clinically meaningful as these values obtained by the modified procedure were well under the threshold acceptable for RSA [3].

CONCLUSIONS

Performing RSA using routine clinical radiographs acquired with DR units and calibrated separately from the patient with a universal calibration object is feasible. This will enable RSA to become a routine imaging tool, beyond limited study use.

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Table 1: Repeatability of the measurements for the three rotation (Rx, Ry, Rz) and translation (Tx, Ty, Tz) axes. Rotations are given in degrees and translations are given in mm.

	Rx	Ry	Rz	Tx	Ty	Tz
Conventional	0.000 ± 0.002	0.000 ± 0.003	0.000 ± 0.002	-0.001 ± 0.003	0.000 ± 0.002	0.000 ± 0.003
Modified	0.001 ± 0.002	0.000 ± 0.002	-0.001 ± 0.003	0.001 ± 0.003	0.000 ± 0.001	0.000 ± 0.003
p-value	<0.001	0.24	0.17	0.14	0.05	0.51

Table 2: Average error of the measurements for the three rotation (Rx, Ry, Rz) and translation (Tx, Ty, Tz) axes. Rotations are given in degrees and translations are given in mm.

	Rx	Ry	Rz	Tx	Ty	Tz
Conventional	0.007 ± 0.015	-0.108 ± 0.053	-0.007 ± 0.021	0.007 ± 0.014	0.004 ± 0.009	0.006 ± 0.012
Modified	-0.010 ± 0.052	0.014 ± 0.032	0.036 ± 0.045	-0.004 ± 0.024	0.006 ± 0.026	0.012 ± 0.035
p-value	0.03	<0.001	<0.001	<0.001	0.28	0.09

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   LHSC, Joint Replacement Institute, receives institutional and educational support from Smith and Nephew, Depuy, and Stryker.

MIGRATION ASSESSMENT USING CLINICAL RADIOGRAPHY AND A SINGLE RSA EXAM.

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INTRODUCTION

Radiostereometry (RSA) is an important tool for the assessment of implant movement. However specialized x-rays required at follow up visits has led to its use predominantly in research.

We hypothesized a patient with RSA markers inserted at surgery, could have implant migration assessed using standard clinical radiographs (e.g. AP views of pelvis and lateral hip) providing a single index RSA exam has been performed.

We therefore developed a bi-planar analysis (BPA) method for routine AP and Lateral hip x-rays which calculates 3D movement of the prosthesis with respect to an index RSA exam. This study reports on a in-vivo validation using an RSA study of acetabular migration.

METHODS

X-rays were used from the first ten patients of an ongoing RSA study of revised impaction grafted and cemented acetabular components. The patients had five to nine 1.0mm tantalum markers implanted in the acetabulum and eight into the polyethylene cup (Marathon XLPE, Depuy, Ireland). RSA images were acquired on the AdoraRSA (NRT, Denmark) with digital Canon CXDI-50C detectors and a calibration box 43 (RSA Biomedical AB, Sweden) in an upright setting. Patients received standing RSA exams at one, six, 13, 26, 52, and 104 weeks. Routine x-rays were postoperatively, one and two years. Routine x-rays comprised a supine anterior posterior low pelvis (AP), and a cross table lateral (LAT) angled at approximately 45 degrees inferior-superiorly. There were no calibration devices or reference plates added to the image views, and positioning of the x-rays was not controlled more than for routine. Patients were repositioned between the AP and the lateral x-ray.

The one year AP and LAT radiographs were analysed using BPA and with the 1 week RSA exam as reference. Firstly, images are measured to determine marker positions, a self calibration stage then determines the film and focus positions and matches measurements to the 3D marker model from the RSA (figure 1). Finally migration between the segments (in this case the cup and pelvis) is calculated.

The BPA one year migration measurement was then compared to the gold standard of RSA calculated from the one week and one year RSA exams.

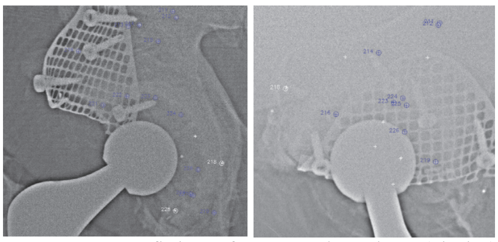

Figure 1. BPA fitting of measured markers (circles) to RSA index (crosses). (a) AP and (b) LAT Hip.

RESULTS AND DISCUSSION

Migration was calculated for the first 10 patients of the study. The difference of cup movement calculated by BPA and RSA is given in table 1. The observed bias (mean error) was not significant. A Bland Altman plot [1] of the axial migration shows good agreement (figure 2).

As was expected, there was poorer agreement medially and anteriorly. This should improve if more markers were identifiable in the lateral view and with less complex images.

The general method was tested using revision hip x-rays where contrast is challenging and where it was hard to identify more than three markers in the lateral view. However, the method is extendable to any marker based RSA application where routine radiographic views at different angles are taken, such as the primary hip, knee or shoulder.

While we analysed migration at one year with respect to the one week RSA, the method may be applied to any time RSA and routine xray time points. For instance, of particular interest it could estimate the post-operative migration *before the index exam* from the immediate post operative clinical radiographs.

Except for bead implantation and one RSA exam, which could be taken at a specialist center at any time post op, this method uses unconstrained clinical radiographs to assess migration. Therefore it could be used at any hospital follow-up clinic, whereas other methods have proposed reference plates and clinical oriented RSA views [2], which would not be available in a general clinic.

	N	Medial	Superior	Anterior
Min	10	-0.306	-0.112	-0.668
Max	10	0.184	0.077	0.369
Mean	10	-0.012	-0.014	-0.088
SD	10	0.143	0.051	0.325

Table 1. Difference in translation between BPA and RSA

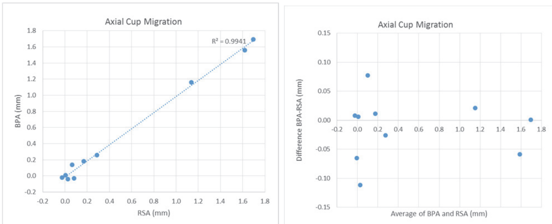

Figure 2. Agreement of BPA and RSA for axial cup migration. (a) Scatter plot, (b) Bland Altman plot.

CONCLUSIONS

The method provided clinically useful migration assessment from a single RSA exam and standard clinical follow-up x-rays. It should therefore be suitable to screen for migration greater than a threshold of 0.3mm and so could bridge the gap between research RSA and routine hospital follow up.

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EQUIVALENT FEMORAL STEM FIXATION WITH HI-FATIGUE AND PALACOS BONE-CEMENTS. A 2 YEAR RANDOMIZED CONTROLLED TRIAL WITH RADIOSTEREOMETRIC ANALYSIS

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INTRODUCTION

Successful long-term fixation of cemented femoral stems relies on several factors including cement adhesion to bone and implant, cement mantle thickness, and cement-fatigue. Hi Fatigue Bone Cement (HF) is a third-generation high viscosity bone cement that initially, during and after mixing, has a lower viscosity compared to Palacos® Bone Cement (P). HF exhibit low viscosity properties during vacuum mixing at room temperature which allows for very low porosity, good mechanical strength, and stable bone-cement interface.

HF exhibit low-viscosity properties during vacuum mixing at room temperature, which allows for very low porosity, good mechanical strength, and a stable bone-cement interface. The dough-time is quick, which makes the cement easy to use, and penetration into the bone should be optimal. In a laboratory fatigue test for cycles to failure at 12.5 MPa loading HF was seven times better compared with P. Excellent 10 year survival is reported with P in CPT-stem (98.7%) [1] and it is considered the gold standard. RSA measured subsidence of cemented femoral stems at 2 years follow-up has been shown to predictive of revision [2]. We aimed to compare the migrations of hip stems inserted with either HF or P.

METHOD

The study design was a patient-blinded, randomized, controlled study. Sample size calculation indicated 23 patients per group. Inclusion criteria were primary hip osteoarthritis, age 71 years and above and pre-operative T-score above -2.5. Exclusion criteria involved severe fracture sequalae, neuromuscular and vascular disease. Ethics approval and clinical database registration was completed. The trial was performed in compliance with the Helsinki II Declaration.

Fifty-two patients were block-randomized to HF (Zimmer) or P (Haereus). Concealed envelopes were drawn in the theater during surgery, and thus the surgeons were not blinded. CPT stems were used (12-14 conus Cr-Co) (Zimmer).

Bone-cements were vacuum mixed with the closed MixiGun vacuum mix system (Zimmer). Six to eight tantalum beads were inserted into the peri-prosthetic femoral bone. During surgery, the time for the different cement phases was registered systematically. Femoral stem migration was measured with EGS-based RSA using static supine stereoradiographs. We used a uniplanar carbon calibration box (Medis Specials, The Netherlands) and a standard RSA setup of two synchronized ceiling-fixed roentgen tubes. Clinical outcomes were Oxford Hip Score (OHS) and VAS pain. Follow-up was performed at postoperative, 3 months, 6 months, 1 year and 2 years.

RESULTS AND DISCUSSION

Mean subsidence was similar (p=0.68) for femoral stems fixed with HF (1.12 mm SD 0.42) and P (1.19 mm SD 0.38) at 2-year follow-up (table 1). There were no significant differences in total translation (p=0.67) and total rotation (p=0.15). Mean OHS was 41.5 (SD 8.6) and mean VAS pain was 1.1 (SD 2.2) (p>0.78) at 2 years.

There were similar working times for mixing, waiting and handling, but the curing time was 2 minutes longer for H (13:43) than P (11:35) (p= 0.00).

CONCLUSION

We found 2 minutes longer curing time but equivalent femoral stem fixation until 2 years follow-up for H in comparison with P. Migrations were similar to other studies of cemented polished stems, and clinical outcomes were above the threshold for acceptable symptoms after THR [3, 4]. Based on this study we expect similar long-term results for fixation of the CPT stem with Hi-Fatigue and Palacos bone cements.

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Table 1:Migrations at one and two years after surgery

	1 yr.	Hi-Fatigue (n=25)	Palacos (n=26)	p	2 yr.	Hi-Fatigue (n=24)	Palacos (n=24)	p
y-translation (mm)		-0.91 (0.28)	-1.03 (0.31)	0.22		-1.12 (0.42)	-1.19 (0.38)	0.68
y-rotation (degree)		0.90 (1.35)	1.39 (1.18)	0.20		1.14 (1.01)	1.75 (1.21)	0.08
MTPM(mm)		1.73 (0.66)	1.67 (0.48)	0.88		1.91 (0.80)	1.88 (0.54)	0.82
Total translation (mm)		1.01 (0.27)	1.10 (0.31)	0.41		1.21 (0.40)	1.27 (0.38)	0.67
Total rotation (degree)		1.51 (0.93)	1.58 (1.06)	0.82		1.46 (0.85)	1.92 (1.07)	0.15

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MIGRATION PATTERN OF AN ANATOMICAL STEM. ONE YEAR FOLLOW-UP WITH RSA

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INTRODUCTION

This prospective study has the aim of evaluating the effect on fixation and early migration by optimizing the biomechanical function of the hip through restoring individual anatomy. We have previously performed a study comparing ABG II modular vs monolithic. These anatomical stems have optimal proximal fit that compensate for differences from left to right side anatomy. Now we present 1 year RSA data for the newly developed Anato stem which has undergone minor changes in design from its predecessors in the proven ABG II concept. The ABG II monolithic and Anato femoral stems maintain equivalent proximal body geometry, taper geometry, neck length and offsets, and indications for use. The main changes are the following:

- PureFix HA Plasma Spray coating on proximal third of the stem
- Stem lengths reduced for ease of use during MIS approaches
- Titanium Alloy (Ti-6Al-4V) instead of TMZF
- Anteverted and neutral version options

We are the first to report the early migration pattern for the new Anato stem.

METHODS

30 patients with primary OA of the hip were included in the study. The patients have so far been followed up with RSA 1 year (postoperatively, 14 days, 3 months and 1 year). CT was performed preop and 2 weeks postop. The outcome questionnaires used were HOOS and EQ5D (preop and 1 year). Preoperative planning was done using Sectras system for conventional 2-D radiographs and more complex 3-D templating software (Ortoma plan) was used on the CT images. This allowed us to decide the exact size and position of the prosthesis based on the contralateral healthy hip anatomy. In this way we aimed at restoring the individual anatomy and therefor gain the most optimal biomechanical solution for every patient.

RESULTS AND DISCUSSION

The Anato stems exhibit a similar migration pattern as its predecessors, the ABG II Modular and Monolithic. The mean subsidence and retroversion was 0.68 mm and 0.85° respectively at 1 year follow-up (figure 1 and 2). The migration was confined to the first 3 postoperative months, whereafter it stabilized suggesting good proximal anatomical fit and osseointegration. The study group shows good function and no revisions or other complications on early clinical follow-up.

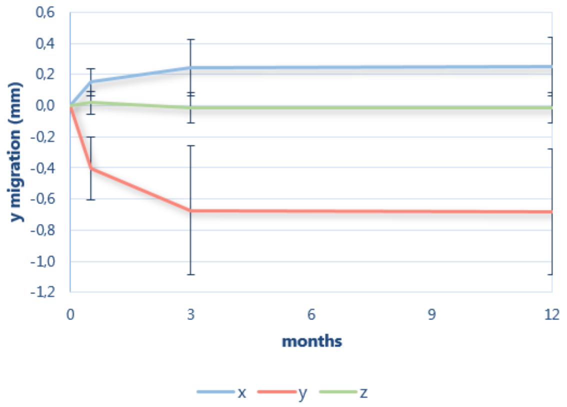

Figure 1: Mean stem subsidence (mm) with 95% CI.

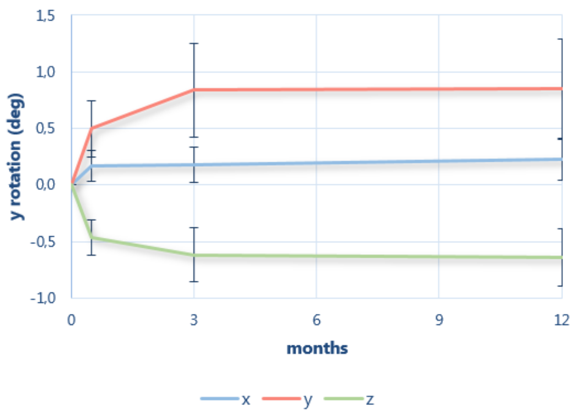

Figure 2: Mean stem rotation (deg) with 95% CI.

CONCLUSIONS

The Anato stem shows benign migratory pattern at 1 year follow-up. The results suggest that the changes done in design from its predecessor (ABG II) has not compromised osseointegration. The migration pattern is similar in the way of settling to its proximal anatomical fit by a slight varus and retroverting tilt.

We will continue the follow-up with RSA at 2 and 5 years. Further we will report on the potential benefits of 3D over 2D templating.

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PROSPECTIVE CLINICAL TRIAL ASSESSING: THE NANOS® SHORT FEMORAL STEM PROSTHESIS IN TOTAL HIP ARTHROPLASTY

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INTRODUCTION

There is a paucity of studies on the Nanos® prosthesis due to its relatively new design. International joint registries do not contain data for the Nanos® stem leaving long-term survivorship and failure rates relatively unknown.

We undertook a prospective clinical trial assessing the Nanos® short stem cementless femoral prosthesis. The primary objective was to assess the implant for subsidence and rotational stability via Radiostereometric Analysis (RSA). The secondary objective was to assess functional outcomes.

METHODS

28 patients undergoing unilateral total hip arthroplasty (THA) using the Nanos® prosthesis were recruited. Data collection points were preoperative, inpatient stay, 3 and 24 months post operatively. RSA radiographs were performed to assess subsidence and rotational stability. Functional analysis was undertaken using the Oxford Hip score (OHS).

RESULTS AND DISCUSSION

The Nanos® stem showed a median subsidence of 0.12mm at 3 months with a further 0.09mm in the 3-24 month interval. (Figure: 1). Median posterior translation of prosthesis head (retroversion) was 0.21mm at 3 months, with a further 0.07mm in the 3-24 months interval. Varus/valgus displacements measured were minimal. The mean OHS improved from 23 preoperatively to 44 at 3 months and 43 at 24 months review. There were 2 early revisions: one for apparent leg length discrepancy and one for early loosening secondary to under-sizing of the implant.

To our knowledge, our study is the first to use RSA to assess migration of the Nanos® stem. It is not for all patients. Our main indications for the prosthesis now include patients with type-A femora (thick cortices and narrow canal) to avoid excessive reaming and those with proximal femoral deformities or hardware in situ precluding the use of a standard stem. We strongly recommend preoperative meticulous templating for stem sizing and only to be performed by an experienced hip surgeon.

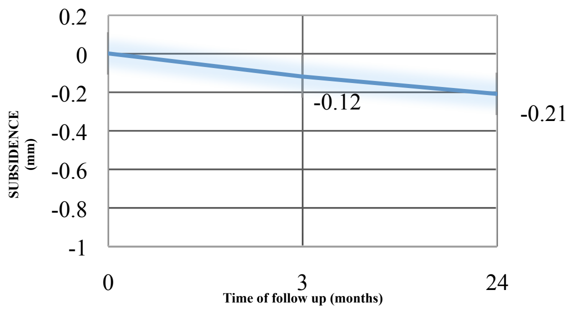

Figure 1: Median Subsidence (mm) at 3 and 24 months follow-ups. (Distal + / Proximal -)

CONCLUSIONS

Patients with Nanos® stem THR demonstrated good stability and excellent short-term functional results, however the high revision rate in our series remains as a point of learning curve.

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Table 1: Pre and Post-operative Oxford Hip Score (OHS) at 3 months and 24 months follow up

Oxford Hip Scores	Preoperative (n=28)	Postoperative	
		0 to 3 months (n=27)	3 to 24 months (n= 25)
Mean (SD)	23 (+/- 6.6)	44 (+/- 4.6)	43 (+/- 5.6)

MIGRATION PATTERN OF A SHORT UNCEMENTED HIP STEM WITH OR WITHOUT COLLAR

A RAMDOMIZED, CONTROLLED RSA STUDY WITH 2 YEARS FOLLOW-UP

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INTRODUCTION

The Furlong Evolution is a short, uncemented femoral stem, which in terms of design, is based on its precursors; the well-proven Furlong HAC, and the recently introduced Furlong Active. The Evolution stem has several new design features to facilitate easier insertion and possible preservation of bone stock by primarily anchoring to the metaphysis of the femur. It is available with or without a collar (figure 1). We have evaluated the migration pattern of the collarless versus the collar-fitted version of the stem in a randomized, controlled trial over 2 years with RSA.

METHODS

50 patients with primary osteoarthritis were randomized to receive either the collar-fitted or the collarless stem. The patients underwent repeated RSA examinations (0, 3, 12, 24 months), conventional radiography and filled out both hip-specific (HOOS) and general health (EQ5D) questionnaires.

RESULTS AND DISCUSSION

Both stem types exhibit a similar migration pattern without any statistically significant differences. The mean subsidence was 0.69 mm for the collarless stem and 0.58 mm for the collared (figure 2) whereas the mean retroversion was 0.96° and 0.71° respectively (figure 3). The migration was confined to the first 3 postoperative months where after the stems seemed to have stabilized, suggesting good osseointegration. Both stem types showed excellent clinical and radiographical results.

CONCLUSIONS

The Evolution stem with or without collar show no sign of unfavourable migration. The results suggest that the new design features do not compromise osseointegration, and the migration pattern is similar to that of its precursors with stabilization within 3 months [1, 2].

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Figure 1: The Evolution stem without (left) and with a collar (right)

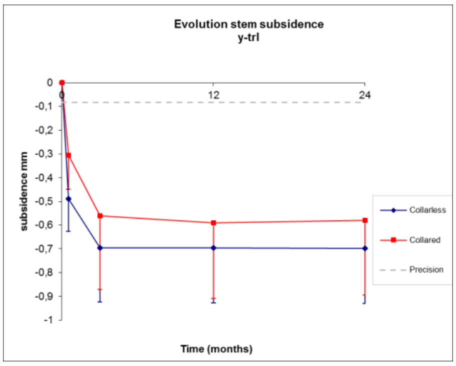

Figure 2: Mean stem subsidence with CI

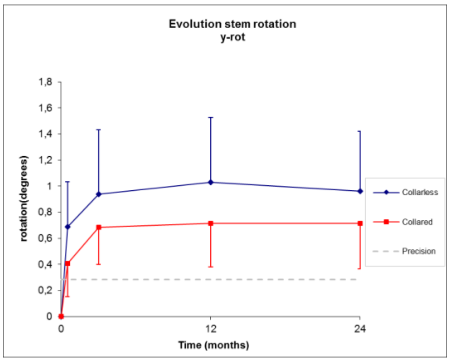

Figure 3: Mean stem rotation with CI

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   JRI Ltd has unconditionally sponsored part of the RSA-analysis and marked the stems with tantalum beads

CHANGE IN ACETABULAR CUP ORIENTATION FROM SUPINE TO STANDING POSITION AND ITS EFFECT ON WEAR OF HIGHLY CROSSLINKED POLYETHYLENE

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INTRODUCTION

Malpositioning of the acetabular cup in total hip replacement has been associated with dislocation, impingement, rim fracture, and greater wear of conventional polyethylene [1]. A "safe zone" for cup position has been debated, and surgeons may frequently miss this zone [2]. It has also been demonstrated that acetabular orientation can change as the patient moves from a supine position to a standing position [3]. The purpose of the present study was to measure acetabular cup position and wear of the highly crosslinked polyethylene liner in the supine and standing position for patients at a minimum of 10 years post-operation.

METHODS

A total of 38 patients were recruited at a mean of 12.5 years post-operation. All patients received a single acetabular cup design (Reflection, Smith & Nephew, Memphis, USA) with a single highly crosslinked liner (Reflection XLPE) and a 28 mm cobalt-chromium femoral head. Patients underwent a novel implementation of a radiostereometric exam in which the x-ray sources and detectors were positioned to obtain an anterior-posterior and cross-table lateral radiograph within a single stereo exam [4]. These exams were conducted with the patient supine and with the patient standing. Acetabular cup position was measured from the radiographs relative to anatomy in a conventional manner [1]. The 3D wear rate was measured using the centre-index method, which includes both creep and wear [5]. The WOMAC, SF12, Harris Hip Score, and UCLA Activity Score was recorded for each patient.

RESULTS AND DISCUSSION

Anteversion (Figure 1A) significantly increased ($p < 0.0001$) a mean of 12° from supine (15.1 ± 10.4°) to standing (27.2 ± 10.5°). Inclination (Figure 1B) also significantly increased ($p = 0.001$) a mean of 2° from supine (44.4 ± 6.8°) to standing (46.3 ± 7.7°). There was no difference ($p = 0.093$) in wear rate (Figure 1C) between supine (0.067 ± 0.070 mm/year) to standing (0.073 ± 0.074 mm/year). The supine to standing measurements were moderately correlated for anteversion ($r = 0.459$, $p = 0.005$), strongly correlated for inclination ($r = 0.866$, $p < 0.0001$), and strongly correlated for wear rate ($r = 0.954$, $p < 0.001$). There were no correlations between cup orientation and wear rate in either position. Supine inclination correlated to the UCLA score ($r = -0.350$, $p = 0.042$).

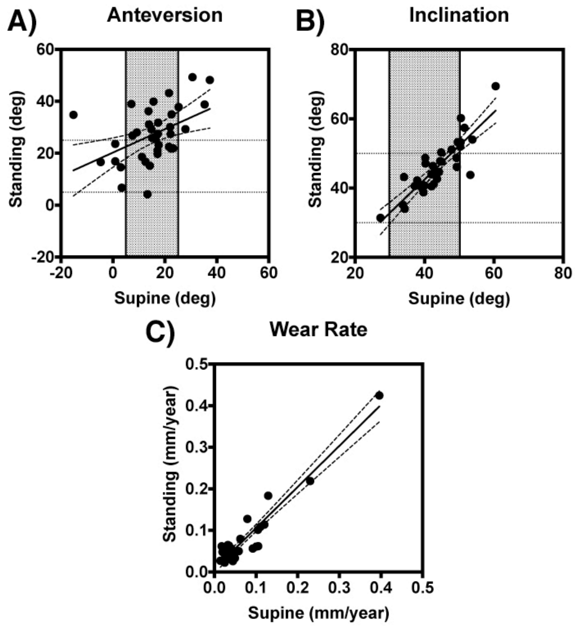

Figure 1 Correlation between supine and standing anteversion (A), inclination (B), and wear rate (C). The vertical grey area and horizontal lines represent the Lewinnek safe zone (A, B).

CONCLUSIONS

Acetabular cup position significantly changes orientation from supine to standing position. However, there was no apparent effect of cup position, either standing or supine, on wear of highly crosslinked polyethylene.

ACKNOWLEDGEMENTS

This study was funded by a Western University Department of Surgery Resident Research Grant.

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   London Health Sciences Centre receives institutional research support from DePuy, Smith & Nephew, and Stryker.

WEAR OF A SECOND-GENERATION XLPE LINER REMAINS LOW AT 10 YEARS: AN RSA STUDY

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INTRODUCTION

A sequentially irradiated and annealed, second-generation highly crosslinked polyethylene (XLPE) liner was introduced clinically in 2005 in an effort to reduce in vivo oxidation. This liner design has also been shown to reduce wear in vitro when compared with conventional and first-generation crosslinked liners. To date, there are only two studies reporting an in vivo wear rate of this liner at 5 years' followup and the measurements are limited as they are made from plain radiographs, which have limited sensitivity, particularly when monitoring very low amounts of wear.

The aim of this study was to measure the amount and direction of wear at 10 years using radiostereometric analysis (RSA) in patients who had THAs that included a second-generation XLPE.

METHODS

We prospectively reviewed 21 patients who underwent primary cementless THA with the same design of XLPE acetabular liner (X3, Stryker) and a 32-mm articulation. Tantalum markers were inserted during surgery and all patients had RSA radiographs at 1 week, 6 months, and 1, 2, 5 and 10 years postoperatively. Femoral head penetration within the acetabular component was measured with UmRSA® software. The results of this cohort have previously been reorted at two [1] and five years [2] postop.

At ten years, three patients had died and one had been revised leaving 17 hips for RSA analysis.

RESULTS AND DISCUSSION

The median proximal, two-dimensional, and three-dimensional wear rates calculated between 1 year and 10 years were all less than 0.01 mm/year with no patient recording a wear rate of more than 0.040 mm/year (Figure 1). Importantly there was no increase in the wear rate between five and ten years.

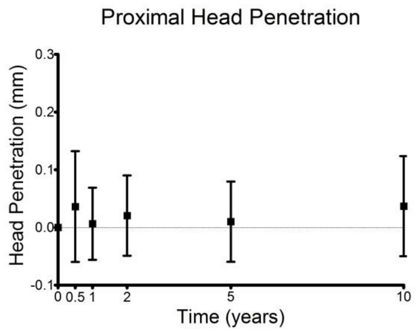

Figure 1: The mean proximal femoral head penetration (mm) over time. Error bars represent standard deviation.

CONCLUSIONS

The wear of a second-generation XLPE liner remained low at 10 years. This low level of wear remains encouraging for the future clinical performance of this material.

ACKNOWLEDGEMENTS

These studies were supported by grants from the NHMRC, Australian Orthopaedic Association, Smith and Nephew, Memphis and the US Department of Defense.

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DAY 2

David Findlay Early Career Researcher (ECR) Award Finalists

CLASSIFICATION OF FRACTURE RISK BASED ON FINITE ELEMENT MODELLING AND CLINICAL PQCT IMAGING OF THE TIBIA

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INTRODUCTION

Bone is an adaptive construct that is continually remodelling due to changes in its local environment. However, for some individuals, adverse changes in the bone structure places them at risk of developing an osteoporotic bone fracture. Unfortunately, current imaging techniques fail to identify many individuals who later fracture [1]. Therefore, new clinical techniques are needed to better classify individuals at risk of fracture. Peripheral quantitative computed tomography (pQCT) is an imaging technique that acquires the bone density distribution in axial cross-sections of the tibia or radius. These images have typically been quantified by total density (ρ_{tot}) and stress-strain indices for bending (SSI_x, SSI_y) and torsion (SSI_{pol}). However, these properties only describe bone stiffness and neglect principal strains within the bone, a quantity that better correlates with fracture load [2]. The aim of this study was to develop a finite element (FE) model based on clinical pQCT imaging to derive the compressive, torsional and bending strength of individual cross-sections. Since these FE models were based on a principal strain failure criteria, it was hypothesized that they would offer improved fracture risk classification compared to existing methods.

METHODS

Two cohorts were considered: (1) fracture group: 26 women (age 63.6±9.8 yrs) who had experienced a low-trauma bone fracture at another skeletal site, and (2) control group: 23 women (38.6±7.1 yrs) who had no tibial fracture history. The contralateral tibia of the fracture group was assumed to be at a greater fracture risk compared to those of the control group. A Stratec XCT-3000 pQCT scanner (resolution 0.4x0.4x2mm) obtained axial images at the 4% and 66% of the tibia length, measured proximally from the distal articular surface. Clinical pQCT variables such as ρ_{tot}, SSI_x, SSI_y and SSI_{pol} were calculated from each image. The pQCT images were segmented and meshed in commercial FE software (Abaqus) with 0.4 mm cubic elements. Three load cases were simulated: compression, torsion, and bending about the minimum neutral axis. In each case, the load or moment was increased until the maximum or minimum principal strain exceeded the tensile or compressive yield strain reported for tibial bone (0.0065ε and 0.0073ε, respectively). The corresponding reaction loads were taken as the compressive (S_{comp}), torsional ($S_{torsion}$) or bending strength (S_{bend}). FE model variables were normalized by BMI to account for different body sizes/shapes. For each pQCT and FE model variable, a logistical regression analysis was performed to derive the area under the receiver operating characteristic curve (AUC). The AUC represents the probability that a classification variable will correctly rank a randomly-chosen fracture patient higher than a randomly-chosen control group patient.

RESULTS AND DISCUSSION

For the 4% and 66% sites, the AUC of all FE model properties were higher than those of the pQCT properties (Table 1). At the 4% site, the FE model properties S_{comp}/BMI and S_{bend}/BMI had the highest AUC (0.95). At the 66% site, $S_{torsion}$/BMI had the highest AUC (0.87). The AUC of all variables was higher at the 4% location compared to the 66% location. Since the 4% site is a trabecular-rich region, these results suggest that, at least for this demographic, changes to trabecular bone provide more sensitive fracture risk diagnosis than cortical bone, as per [3].

Table 1: Area under the receiver operating characteristic curve (AUC) of pQCT and FE model variables. **p-value <0.001

		4% Site			66% Site		
	Variable	AUC	CI low	CI high	AUC	CI low	CI high
pQCT	ρ_{tot}	0.89**	0.77	0.96	0.70**	0.53	0.83
pQCT	SSI_x	0.83**	0.68	0.92	0.75**	0.59	0.87
pQCT	SSI_y	0.84**	0.70	0.93	0.78**	0.64	0.90
pQCT	SSI_{pol}	0.85**	0.71	0.94	0.78**	0.62	0.91
FE model	S_{comp}/BMI	0.95**	0.84	0.99	0.82**	0.67	0.91
FE model	$S_{torsion}$/BMI	0.92**	0.81	0.98	0.87**	0.69	0.92
FE model	S_{bend}/BMI	0.95**	0.86	0.99	0.84**	0.68	0.93

CONCLUSIONS

The FE models based on clinical pQCT imaging demonstrated a greater capacity to classify individuals with greater fracture risk compared to clinical pQCT variables. Since these models were based on clinical pQCT scanning protocols, they require no additional radiation dose and, due to their simplicity, their implementation may be automated for clinical fracture risk assessment.

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In situ bioscaffold 3D printing for cartilage regeneration in a large animal model. Pilot study.

[1]Claudia Di Bella, [2]Cathal O'Connell, [1]Romane Blanchard, [1]Serena Duchi, [1]Cheryl Augustine, [3]Zhilian Yue, [4]Stewart Ryan, [5]Peter Pivonka, [3]Gordon Wallace and [1]Peter Choong

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INTRODUCTION
Articular cartilage injuries experienced at an early age lead to the development of osteoarthritis later in life. Current surgical and biological techniques fail to demonstrate the ability to regenerate hyaline cartilage *in vivo* that maintains its property in the long term[1]. *In situ* 3D printing is an exciting and innovative bio-fabrication technology to deliver tissue-engineering techniques by the surgeon at the time and location of need. We have created a hand-held extrusion ink-jet printing device (Biopen) that allows the simultaneous and co-axial extrusion of Bioscaffold and cultured cells directly *in vivo* into the defect that needs to be repaired[2]. Preliminary data have shown that bioscaffolds printed using the Biopen can produce hyaline-like cartilage *in vitro*[3]. This pilot study aimed at assessing the use of the Biopen *in vivo* to repair a full thickness chondral defect in a large animal model.

METHODS
An 8-mm circular critical sized full thickness chondral defect has been created in the weight-bearing surface of the lateral and medial condyles of both femurs of 8 sheep. Each defect has been treated with either (i) hand-held *in situ* 3D printed bioscaffold using the Biopen (HH group), (ii) pre-constructed bench-based printed bioscaffolds (BB group), (iii) micro-fractures (Clinical Group) or (iv) left untreated (Negative Control Group). Animals have been euthanized at 8 weeks, histology and IHC have been performed in the retrieved condyles and scored according to the O'Driscoll score. Biomechanical indentation tests have been performed to assess the physical properties of the regenerated cartilage tissue.

RESULTS AND DISCUSSION
Both the HH Biopen and BB printed bioscaffolds (i) remained in place for the duration of the experiment (8 weeks), (ii) do not induce inflammatory or foreign body reaction, (iii) allow early cartilage formation which shows better histological and mechanical properties to microfractures and untreated defects (Fig 1).

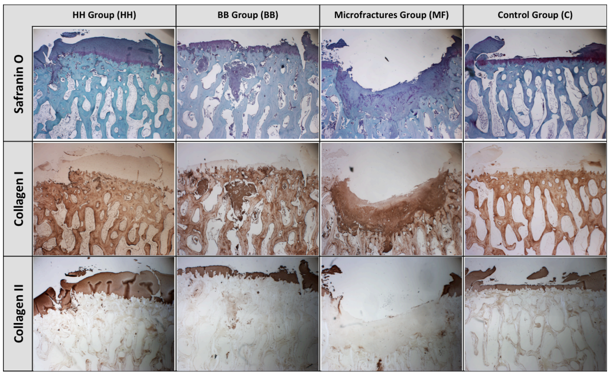

Figure 1: Histology (SafraninO staining) and immunohistochemistry (Collagen I and II) show good quality hyaline-like cartilage formation in the HH group

CONCLUSIONS
Cell printing is a feasible means of delivering regenerative medicine techniques *in vivo*. Early data of direct bioprinting in a large animal model show that the Biopen can be used to regenerate articular cartilage.

ACKNOWLEDGEMENTS
This study has been partially funded by Arthritis Australia – Zimmer Australia grant, and by the Research Endowment Funds – St Vincent's Hospital, Melbourne.
Funding from the Australian Research Council Centre of Excellence Scheme (Project Number CE 140100012) is gratefully acknowledged. GGW is grateful to the ARC for support under the Australian Laureate Fellowship scheme (FL110100196). The authors also gratefully acknowledge the use of facilities within the Australian National Fabrication Facility (ANFF).

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Quantification of peri-implant bone strain during screw tightening using digital volume correlation

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INTRODUCTION

Stripping during screw insertion occurs with an incidence as high as 50% [1]. With an increase in age and osteoporosis, overtightening is more likely as surgeons try to achieve torques values similar to th observed in young, healthy bone. Stripping torque can be predicted based on the torque at head contact [2]. The question remains however: “how tight is tight enough?”. Due to the diffusion of in situ biomechanical imaging (mainly via micro-CT), digital volume correlation (DVC) has become a powerful tool to measure full-field internal deformations in bone and bone-biomaterial systems [3,4]. This study uses a time-elapsed micro-CT imaging of the bone-implant interface, in combination with DVC. The aim is to quantify the deformation induced on the trabecular bone at the bone-implant interface for each rotation step, with increased tightening torque.

METHODS

Cancellous lag screws (Ø7.0mm) were inserted into excised human femoral heads by step-wise tightening between head contact and stripping using a novel testing device within the micro-CT scanner [5] (Skyscan model 1076, Skyscan-Bruker, Belgium). At each time point, micro-CT datasets (voxel size: 17 µm) of the bone-implant interface were obtained. Insertion torque, compression under the screw head and angular rotation were simultaneously measured throughout insertion. The screw was masked out from the micro-CT images (“CTAnalyzer”, Skyscan-Bruker, Belgium). DVC (“DaVis 8.3”, LaVision, Germany) was used to register 3D images at different tightening levels between head contact (reference scan) and maximum torque, providing the full-field strain developed at the bone-screw interface. Strain uncertainties were computed from sequential scans of a volume of interest distant from the screw region. Error minimization with sufficient spatial resolution was achieved with a multi-pass approach and final sub-volume of 48 voxels [3]. These setting were then used for all the computations under load.

RESULTS AND DISCUSSION

DVC was able to compute the strain experienced by the bone tissue around the screw for the different tightening levels. Significant deformation occurred within the peri-implant bone, decreasing radially (Figure 1). Depending on the region, the calculated principal tensile strains ranged from 0 to ~20000 με for the 60% tightening and up ~50000 με for the maximum tightening (Figure 1).

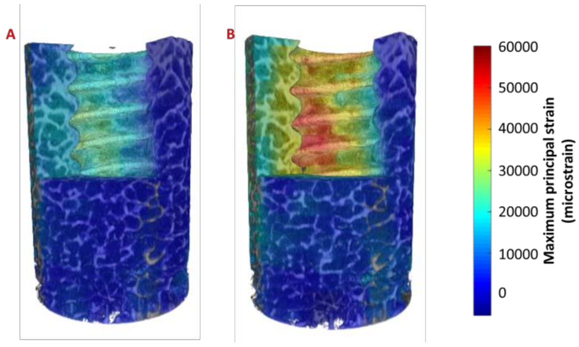

Figure 1: Principal tensile strain distribution obtained using DVC on micro-CT scans of the trabecular bone (VOI Ø18mm) around the screw, for tightening levels of 60% (A) and 100% (B).

Our preliminary findings indicate that during screw tightening, most of the deformation occur in trabeculae close to the screw and decreases radially, in accordance with the finite element predictions reported in literature [6]. The calculated local strains suggest that at 100% tightening, large areas of bone tissue in contact with the screw experienced yielding [7].

CONCLUSIONS

DVC was able to couple deformation visible at the bone-screw interface with the strain field produced in trabecular bone, at different levels of tightening. This procedure can be useful for validation of finite element models in future.

ACKNOWLEDGEMENTS

We thank the Australian National Health and Medical Research Council (NHMRC) (Grant ID 595933) and Flinders University (Fellowship Tozzi).

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DAY 2

KEYNOTE 3 – Prof Bernd Grimm

Session Sponsor

PHYSICAL ACTIVITY: CLINICAL OUTCOME PARAMETER, DIAGNOSTIC BIO-MARKER OR MEDICINE. POSSIBILITIES FOR WEARABLE SENSORS IN ORTHOPAEDICS .

Bernd Grimm

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The impact of physical activity (PA) on general health and for the development, prevention or treatment for various diseases is increasingly being recognized. As result physical activity has already been proclaimed as the "Medicine of the 21st century" or the "closest thing to a miracle drug" while the opposite, inactivity or sedentary lifestyles, has culminated in declaring "Sitting as the new smoking," in health promotion programs.

In orthopaedics where the movement apparatus is directly affected by pathology or trauma and where interventions such as surgery aim to restore physical activity levels, measuring PA seems of particular relevance for diagnosis or outcome assessment. Physical activity assessment using patient self-reports has been available but suffers from high subjectivity and poor validity so that for no instrument adequate measurement properties could be shown.

Wearable technology such as accelerometers, gyroscopes and sensors measuring other modalities such as barometric pressure for elevation changes have proliferated enabling the objective assessment of physical activity in the free field.

In this lecture, the impact of PA on various diseases and its relevance and the benefit of measuring it in the orthopaedic context is described. A brief overview is given of the available sensor technology, its functionality and the specific needs and challenges for the use in orthopaedics as opposed to applications in general health or epidemiological studies.

In addition, the basic principles of algorithm development for the classification of PA are presented and the particular solution developed by the author's group is described as an example. In this context the types, levels and orthopaedic relevance of various PA parameters is being discussed.

The application of activity monitors in various studies in clinical orthopaedics is presented to show how parameters of habitual physical activity can a) reveal the impact of orthopaedic disease and treatment on general health related activity levels, b) serve as a powerful objective outcome parameter for clinical studies, c) function as an activity biomarker in the early diagnosis of disease or d) create a measure for patient feedback and coaching.

Furthermore, challenges with the technology, parameters and clinical application are mentioned and a future outlook is presented.

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DAY 2

ANZORS PhD Award Finalists

QUANTITATIVE EVALUATION OF FACET DEFLECTION, STRAIN AND FAILURE LOAD DURING SIMULATED CERVICAL SPINE TRAUMA

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INTRODUCTION

Traumatic cervical facet dislocation (CFD) is often associated with devastating spinal cord injury [1]. The injury mechanisms leading to traumatic CFD are complex and have not been replicated in biomechanical testing [2]; however, anterior shear and flexion loading modes are likely associated with dislocation [3]. Concomitant facet fracture is commonly observed in cases of CFD [4], yet quantitative measures of facet strain, stiffness and failure load have not been reported. A better understanding of the mechanical behaviour of the facets during cervical trauma is important for validating computational models and the development of preventative measures. The aim of this study was to determine the mechanical response of the facets when loaded in directions thought to be associated with traumatic CFD – anterior shear and flexion.

METHODS

Thirty functional spinal units (FSUs; 6×C2/3, C3/4, C4/5, C5/6 and C6/7) were dissected from thirteen fresh-frozen human cadaver cervical spines (mean age = 70 yrs [range 48-92], seven male and six female). Musculature was removed and the vertebral disc and bilateral facet joint capsules were preserved. Vertebral bodies of each FSU were embedded such that a rectangular block of polymethylmethacrylate (PMMA) protruded approximately 50 mm from the superior endplate of the superior vertebra. The specimen-PMMA assembly was rigidly mounted to the base of a materials testing machine (Instron 8874) via a custom support apparatus attached to a rotary table. Using the rotary table, the inferior articular facet surfaces of the inferior vertebrae were positioned relative to the actuator to simulate *in-vivo* 1) flexion and 2) anterior shear loading. Three cycles of uniaxial sub-failure loading to 100 N (10 N pre-load) were applied bilaterally at 1 mm/s using 6 mm diameter hemispherical loading pins, in each loading direction; the last cycle was used for analysis. Each specimen was failed in a randomly assigned direction at 10 mm/s. Deflection of the facets was measured using a motion capture system (Optotrak Certus, Northern Digital). Principal strains at the bilateral facet bases were calculated from the output of rosette strain gauges (TML, Tokyo). Apparent facet stiffness was determined from the linear region of load-displacement data and initial failure load was quantified for destructive tests. Paired and independent t-tests were used for comparison of non-destructive and destructive parameters, respectively (α=0.05). FSUs from different vertebral levels were grouped.

RESULTS AND DISCUSSION

Apparent facet stiffness and failure load were significantly greater in flexion than in anterior shear (Figure 1). These stiffness measurements corresponded with significantly larger maximum principal strains (p=0.002) and sagittal facet deflections (p=0.046) for the non-destructive anterior shear tests. Failure occurred through the facet tip when subjected to anterior shear loading, while failure through the pedicles was most common for simulated flexion loading. Subsequent linear mixed effects models will be used to account for vertebral level, donor demographics, and bone mass density.

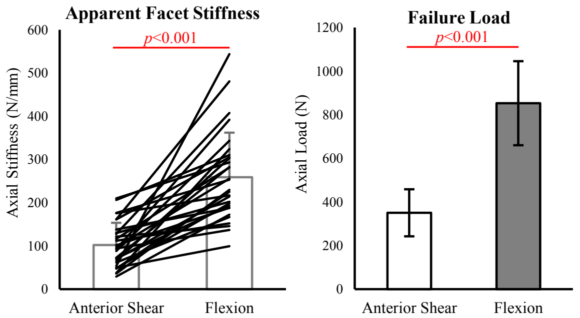

Figure 1: Paired and mean (+1 SD) facet stiffness values (left), and mean (±1SD) failure load (right) for anterior shear vs flexion loading directions.

CONCLUSIONS

Cervical facets tended to be stiffer, and have a higher failure load, when loaded in flexion compared to anterior shear, and failure location was dependent on loading mode. This is the first of a series of experimental studies relating to CFD and it is anticipated that the information gained will assist with the validation of finite element models of cervical trauma.

ACKNOWLEDGEMENTS

Funding was provided by AOSpine Australia New Zealand (AOSAUNZ2015-03), the Royal Adelaide Hospital Research Fund and the Australian Postgraduate Award.

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VITAMIN D ACTIVITY DIRECTLY REGULATES OSTEOCLASTOGENESIS AND RESORPTIVE ACTIVITY

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INTRODUCTION

Mature osteoclasts express the 1α-hydroxylase enzyme (CYP27B1) and vitamin D receptor (VDR) and are able to synthesise and respond to $1,25(OH)_2D_3$[1,2,3]. Despite indirect signalling by osteoblasts via the receptor activator of nuclear factor kappa-B ligand (RANKL) being well characterised, the *in vivo* demonstration of whether vitamin D activity directly within mature osteoclasts is necessary for the regulation of their activity is not yet understood. To examine this, a mouse model was created whereby VDR was deleted conditionally in osteoclasts using the Cre-LoxP approach.

METHODS

$Ctsk^{Cre}/Vdr^{-/-}$ mice were generated by mating floxed VDR mice ($Vdr^{fl/fl}$) with Cathepsin-K-Cre (*CtskCre*) mice. 3-week old male $Ctsk^{Cre}/Vdr^{-/-}$ mice and littermate controls ($Vdr^{fl/fl}$), were fed either a standard chow diet (NormCaP) or a 0.8% Calcium and 0.7% Phosphorous (LowCaP) diet for 3 weeks. Mice were humanely killed at 6-weeks of age for assessment, with bone histomorphometric analysis of the vertebra conducted using *ex vivo* micro-computed tomography (µCT) imaging (Skyscan 1174). For *in vitro* studies, splenocyte-derived osteoclasts were generated from 8-week old mice and co-cultured with osteocyte-like MLO-Y4 cells in the presence of differentiation media containing sub-optimal concentrations of recombinant M-CSF (10ng/mL) and RANKL (10ng/mL), with or without added $1,25(OH)_2D_3$ (1nM). The number of $TRAP^+$ osteoclasts and their resorptive activity was assessed (Day 10 data shown).

RESULTS AND DISCUSSION

As depicted in figure 1, six-week old male $Ctsk^{Cre}/Vdr^{-/-}$ mice fed a NormCaP diet demonstrated a 10% reduction in vertebral trabecular bone volume which was associated with a modest increase in osteoclast size ($p<0.05$). However, when young male $Ctsk^{Cre}/Vdr^{-/-}$ mice were fed a LowCaP diet, vertebral BV/TV% was markedly decreased by a further 22% compared to control mice on the same diet ($P<0.05$). While these data suggest that $Ctsk^{Cre}/Vdr^{-/-}$ mice exhibit enhanced osteoclast-driven bone resorption under suboptimal dietary conditions, no differences were found in the circulating resorption marker CTX or the numbers of $TRAP^+$ osteoclasts in bone. *Ex vivo* studies illustrated that splenocyte-derived osteoclast precursors from $Ctsk^{Cre}/Vdr^{-/-}$ mice have increased capacity for osteoclastogenesis in a co-culture with intact VDR signalling in the stromal (MLO-Y4) compartment, generating osteoclasts with increased size (nuclei number) and resorption activity when compared to cells from control $Vdr^{fl/fl}$ mice.

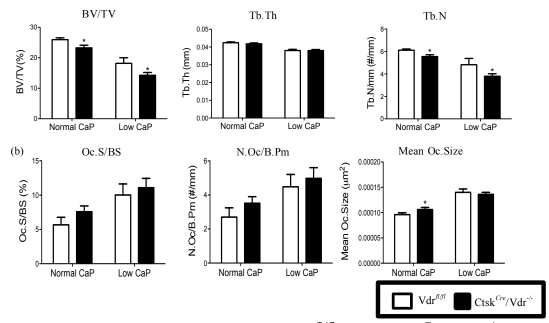

Figure 1: Vertebral bone histomorphometry. Data presented as means ± SEM, n=5-12. a) Vertebral bone volume analysis using µCT and b) Vertebral bone histomorphometry in the vertebra of male 6wk old floxed $Vdr^{fl/fl}$ and $Ctsk^{Cre}/Vdr^{-/-}$ mice fed a NormalCaP or a LowCaP diet. Unpaired T-Test ($^*p<0.05$).

CONCLUSIONS

Our findings suggest that in addition to RANKL-mediated osteoclastogenesis, an intact $1,25(OH)_2D_3$/VDR signalling mechanism is required for the direct regulation of the differentiation, activity and survival of osteoclasts in both *in vivo* and *ex vivo* settings.

ACKNOWLEDGEMENTS

This work was funded by a NHMRC Project Grant.

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PROXIMAL TIBIA SUBCHONDRAL BONE MICROARCHITECTURE IN VARUS AND VALGUS-ALIGNED OSTEOARTHRITIC KNEES: COMPARISONS WITH CONTROLS

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INTRODUCTION

In knee osteoarthritis (OA), subregional changes to the proximal tibia subchondral trabecular bone (STB) microarchitecture, important in disease pathogenesis, may reflect an adaptation to abnormal joint loading [1]. Between varus- and valgus-aligned OA joints, subregional differences in proximal tibia STB microarchitecture have been reported [2]. However, reports on differences in STB microarchitecture between OA and the non-pathological joint are conflicting [3,4]; moreover, whether and how joint alignment influences these results, to date, remains unexplored.

The aim of this study was to quantify proximal tibia subchondral trabecular bone microarchitecture of end-stage knee OA patients with varus or valgus-aligned joints and compare it to control (non-OA) knees.

METHODS

Participants: Tibial plateaus were retrieved from 25 end-stage knee OA patients (age 68±7years, mass 92±18kg) who underwent total knee arthroplasty, and from 15 cadaveric donors (age 61±13years, mass 84±17kg) without evidence of musculoskeletal disease in the examined knee joint (controls, n=15). OA joints were classified as varus (n=18) or valgus-aligned (n=7), determined from the mechanical axis deviation measured from plain radiographs.

Micro-CT: Entire tibial plateaus were micro-CT scanned (17µm/voxel, Skyscan 1076, Skyscan-Bruker, Belgium). STB microarchitecture, including bone volume fraction (BV/TV), were analysed in 4 cylindrical subregions of interest (ROIs, 10mm diameter, 3-5mm length) in the antero-medial (AM), antero-lateral (AL), postero-medial (PM) and postero-lateral (PL) condyle (Fig. 1(a)). Medial-to-lateral (M:L) BV/TV ratios among the 4 ROIs were also explored.

Statistics: Differences in STB microarchitectural parameters and BV/TV ratios for each OA group (varus, valgus), compared to controls, were assessed by Bonferroni-adjusted Mann-Whitney U-tests. Statistical significance, $p<0.05$.

RESULTS AND DISCUSSION

Age and body mass did not significantly differ between OA and controls. Compared to controls, in varus OA, BV/TV was significantly higher (up to +41%) in medial (AM, PM) ROIs, whereas in valgus OA it was higher (up to +80%) in lateral (AL, PL) ROIs Fig. 1(b)). In varus, all M:L BV/TV ratios ranged between 1.4 and 2.4 and were significantly higher (up to +58%) in AM:PL, PM:AL and PM:PL compared to controls (range 0.9-2.0). In valgus, ratios were closer to unity (range 0.9-1.2), with AM:AL and PM:AL BV/TV ratios significantly lower (-39 to -40%) than in controls (Fig. 1(c)).

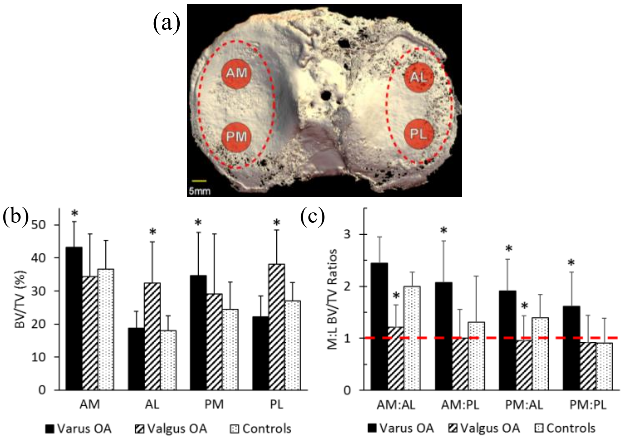

Figure 1: (a) 3D micro-CT image of tibial plateau (right knee) showing position of the 4 ROIs examined, (b) average BV/TV and standard deviation (error bars) in the 4 ROIs, (c) average M:L BV/TV ratios (dashed line indicates unity; *$p<0.05$ compared to controls).

CONCLUSIONS

This study revealed subregional differences in proximal tibia STB microarchitecture and M:L BV/TV ratios between OA patients and controls depending on joint alignment. STB BV/TV was significantly higher from normal medially in varus, laterally in valgus. Accordingly, compared to normal, M:L BV/TV ratios were higher in varus and lower in valgus; taken together these results likely reflect a microarchitectural adaptation in OA to differences, from normal, in the medial-to-lateral load distribution upon the tibial plateau. Detectable differences in STB microarchitecture between the OA and non-OA joint are dependent on alignment and could become, in future, useful indicators of disease progression.

ACKNOWLEDGEMENTS

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Prediction of the hip joint centre for musculoskeletal models using an articulated shape model of the pelvis in patients with end-stage hip osteoarthritis.

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INTRODUCTION

Accurate scaling for musculoskeletal models is important to enable more accurate simulations to predict muscle and joint contact forces. Virtual hip joint centre markers, using regressions equations or functional methods, are recommended to improve the accuracy of scaling [1]. In patients with end-stage hip osteoarthritis, estimation of the hip joint centre (HJC) can be confounded by increased soft-tissue and limited range of motion due to pain [2]. Non-linear scaling (NLS) using segmented surfaces from reconstructed medical images provides a more advanced method to more accurately predict the location of the HJC.

The aim of this study was to compare the accuracy of HJC estimation from an articulated shape model of the pelvis to six commonly reported regression-based methods.

METHODS

A statistical shape model of the pelvis was created from a training set of 19 manually segmented bones from post-mortem [3]. Initially, pelvis shape and size was registered to an osteoarthritic (OA) patient's motion capture data using the Anterior Superior and Posterior Superior Iliac Spines landmarks, to generate the best fit model (minimal sum of squared distance) from the training set.

The generated model was then optimised to register the pelvis model to manually segmented data from the OA patient. A two-stage fitting process comprised of an iterative closest point registration and secondly a local fit optimising the coordinates of each mesh control point individually to reduce the RMS error between the model mesh and the individual's segmented CT.

The accuracy of the generated model to predict the location of the HJC was validated using the ground-truth HJC location from the reconstructed CT, with the results compared against estimations from traditional regression methods (Harrington, Bell, Seidel, Tylkowski, and Andriacchi).

RESULTS AND DISCUSSION

Compared to the CT based HJC (reference), the HJC generated using NLS demonstrated a Euclidean mean difference of 7 mm, (max = 11.5 mm, min = 1.7 mm). The prediction of the HJC location from the NLS showed significantly lower difference from the ground-truth CT image compared to the estimated HJC locations from six commonly reported regression equations (Figure 1). Predictions using the Harrington equation were the most comparable to the generated model and the ground-truth, although a significant difference was still observed (mean = 8.9 mm, max = 16.9 mm; min = 4.8 mm).

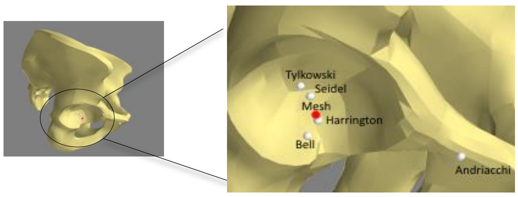

Figure 1: An illustration of the HJC location generated from the statistical shape method (red) and regression methods (white)

CONCLUSIONS

The generation of a subject specific model from statistical shape techniques provides a more accurate prediction of the HJC location compared with those calculated from regression equations.

ACKNOWLEDGEMENTS

NIL

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DAY 2

RSA PhD Award Finalists

THE ROLE OF RADIOSTEREOMETRIC ANALYSIS IN THE EVALUATION OF ORTHOPAEDIC IMPLANTS IN THE UPPER EXTREMITY

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INTRODUCTION

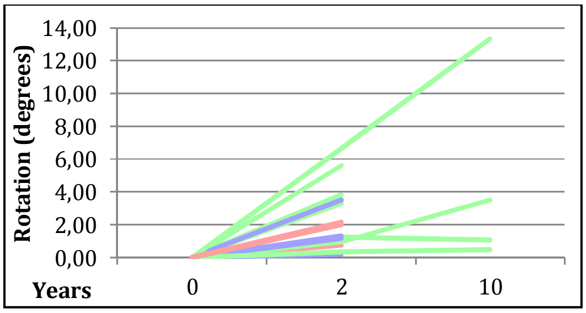
Since a relation has been shown between early migration measured by RadioStereometric Analysis (RSA) and future loosening of total knee and hip prostheses, [1,2] RSA plays an important role in the development and evaluation of prostheses. However, only a few RSA studies of the upper limb have been performed and the value of RSA in upper limb arthroplasty is not yet clear. We therefore performed a systematic review to investigate accuracy and precision of RSA in the upper limb.
In a second study we investigate the predictive value of early migration of the Instrumented Bone Preserving (IBP) elbow prostheses for revisions in the long term.

METHODS

A systematic search of the literature was performed. Articles concerning RSA for the analysis of early migration of upper limb prostheses were included. Quality assessment was performed using the MINORS score, Downs and Black checklist, and the ISO RSA standard. Data were extracted using a predefined template.
To investigate the predictive value of early migration of the IBP elbow prosthesis, 2-year migration data of 16 prostheses have been reported in a previous study.[3] The 2-year migration data of prostheses that have been revised during follow-up were compared with early migration data of the non-revised group.

RESULTS AND DISCUSSION

23 studies were included in our systematic review. Precision values were in the 0.06–0.88 mm and 0.05–10.7° range for the shoulder, the 0.05– 0.34 mm and 0.16–0.76° range for the elbow, and the 0.16–1.83 mm and 11–124° range for the TMC joint. Accuracy data of marker- and model-based RSA were not reported in the studies included.
Of the sixteen patients included in our previous study, eleven were still alive at a mean follow-up of 140 months. Four of the patients who were still alive had undergo a revision at a median follow-up time of 95,5 months. Median total translation and rotation two years postoperatively was 0.16 mm and 1.26˚ in the revised prostheses and 0.68 mm and 2.00˚ in the non-revised prostheses. No relation could be found between early migration and revision. Long-term migration values could be obtained in four patients. The migration patterns varied widely (figure 1).



CONCLUSIONS

RSA is a precise method for measuring migration of orthopedic implants in the upper limb. However, the precision of rotation measurement is poor in some, mainly symmetrical shaped components. Other challenges with RSA in the upper limb include the limited size of surrounding bone, leading to over-projection of the markers by the prosthesis.
Further, we present the first long-term RSA study of the IBP elbow prosthesis. This study could not prove a relation between early migration of the IBP elbow prosthesis and long-term survival.
More extensive research into the role of RSA in the upper limb is required to give more insight in early migration as a predictor of long-term survival. We recommend higher adherence to RSA guidelines and encourage investigators to conduct long-term follow-up RSA studies.

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THE MIGRATION OF ACETABULAR COMPONENTS USED AFTER COMPLEX ACETABULAR RECONSTRUCTIONS

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INTRODUCTION

Acetabular components used at revision total hip replacement (THR) to treat severe bone defects have previously reported poor survivorship (50% at 3 years). Early migration of the acetabular component is associated with later loosening in primary THR; although this has not been established for components used at revision THR. The ability to predict loosening may facilitate the early assessment of new prostheses and surgical techniques used to treat severe bone defects.

The aims of this thesis were to: **1)** determine if early migration predicts later loosening of uncemented acetabular components used at revision THR, **2)** determine the diagnostic capability of migration at late follow-up to diagnose loosening, **3)** to determine if porous tantalum components provide sufficient stability to treat large acetabular defects, **4)** to validate implant-bone contact measurements made from computed-tomography (CT) scans and determine if the amount of contact influences the stability of porous tantalum acetabular components.

METHODS

Study 1&2: We retrospectively analysed two patient groups; Group A: Components found not loose at re-revision and Group B: Components found loose at re-revision. All revision THRs that underwent re-revision surgery in our institution between 1978 and 2015 were considered for this study. The intraoperative loosening grades were retrieved from operative records. Migration was measured using EBRA analysis of serial AP pelvis radiographs.

Study 3: Radiostereometric analysis (RSA) was used to monitor the migration of a prospective cohort of 59 consecutive tantalum acetabular components used to treat severe bone defects (Paprosky II and III). Migration thresholds from Study 1 were applied to the results of this cohort.

Study 4: CT scans were taken of 6 cadaver specimens with a tantalum acetabular component in place. Each specimen was then fixed and sectioned (1mm slice thickness). The amount of implant-bone contact was assessed on each slice and compared to measurements made from CT scans. 32 hips in Study 3 had CT scans taken within one week post revision THR. The bone-implant contact was assessed and compared to the amount of early migration at 12 and 24 months.

RESULTS AND DISCUSSION

Study 1: The mean proximal translation and sagittal rotation were significantly higher in Group B than in Group A from 3 months ($p < 0.02$, Fig 1). Proximal translation >1.0mm within 24 months had a positive predictive value (PPV) of 90% and a specificity of 94%, but a sensitivity of 64%. Proximal translation >1.0mm within 24 months correctly identified 76 of 94 (81%) of components to be either loose or not loose [1].

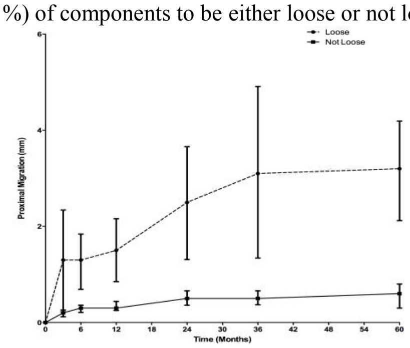

Figure 1: Mean acetabular proximal translation over time for Group A (Not loose) and Group B (Loose)

Study 2: Using EBRA, both proximal translation and sagittal rotation were excellent diagnostic tests for detecting aseptic loosening [2]. The area under the receiver operating characteristic (ROC) curves was 0.94 and 0.93, respectively. The thresholds of 2.5 mm proximal translation or 2° sagittal rotation (EBRA) in combination with radiolucency criteria had a sensitivity of 93% and specificity of 88% to detect aseptic loosening.

Study 3: The mean proximal translation at 24 months for all components was 0.77mm (range -0.63 to 16.4, 95% CI 0.12-1.30). The mean migration of all acetabular components not revised for loosening was 0.21mm (range -0.63 – 2.7, 95% CI 0.08-0.36), while the mean migration of the five components revised for loosening was 6.9mm (range 3.2-16.4, 95% CI -0.07 – 13.8).

CONCLUSIONS

EBRA can be used as accurate diagnostic tools to detect and predict aseptic loosening of cementless acetabular components used at revision THA. The migration patterns of porous tantalum acetabular components used to treat severe acetabular bone defects were similar to the migration of primary acetabular components.

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CONFLICT OF INTEREST DECLARATION

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

If you have accepted any support such as funds or materials, tangible or intangible, concerned with the research by the commercial party such as companies or investors, choose YES below, and state the relation between you and the commercial party.

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1. The author(s) did receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity.
   Zimmer PTY LTD partly funded a project involving RSA measurements of porous tantalum components

RSA and Inducible Displacement for evaluation of orthopaedic implants.

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INTRODUCTION

Even though approximately 90% of Total Knee or Hip Prosthesis (TKP or THP) function well for at least 10 years, the most common failure mode is aseptic loosening, accounting for approximately 22% of all failures (1-3). Although the exact process of aseptic loosening is not yet completely understood, it is believed to be multifactorial. It is initiated both by a response of macrophages to wear particles and by trabecular bone resorption at the cement-bone or implant-bone interface (4). This process can lead to continuous migration of the implant with subsequent pain. The only solution at that point is to perform revision surgery, which results in higher costs, increased risk of complications during surgery and an overall lower rate of success.

Migration of orthopaedic implants can be assessed with sub-millimeter accuracy using radiostereometric analysis (RSA) (5-7). However, due to its high accuracy RSA can also be used to measure 'Inducible Displacement', which is defined as a reversible displacement of a prosthesis with respect to the host bone as a result of applying a load to the joint. In this PhD-research we therefore not only use RSA in the conventional way, but also plan to assess the correlation between the amount of migration over time and measured Inducible Displacement. We expectthis will provide us with a novel method to more easily identify individual patients at risk of loosening. At the same time it will allow us to safely discharge patients from further follow-up and thus overtreatment if there is only minimal Inducible Displacement, meaning the implant is properly fixed.

STUDIES OVERVIEW AND AVAILABLE RESULTS

In the (high-viscosity) Palacos vs (low-viscosity) Palamed-bone cement study, we performed a randomized controlled trial involving 39 patients (40 hips) undergoing primary total hip replacement. All patients received a cemented Stanmore THP; 22 patients (22 hips) were randomized to Palacos and 17 patients (18 hips) were randomized to Palamed. Migration was determined by RSA. None of these 40 hips had been revised at the 10-year follow-up mark. No statistically significant or clinically significant differences were found between the 2 groups for mean translations, rotations, and maximum total-point motion (MTPM).

In the Malalignment vs Migration in TKP study we measured three different angles on the post-operative whole-leg CT-scans of 26 NexGen and 4 Mobile-bearing ROtating Concave Convex (ROCC) TKPs. In the transverse plane, lines were drawn between anatomical landmarks and then propagated through the whole CT-series so the angles between them could be measured (i.e. the Ankle-Tibia angle (ATA), the Tibia Component Rotation (TCR), and the Femoral Mismatch Angle (FMA)). These angles were then put in a Mixed Model Analysis to analyze their effects on MTPM during follow-up (6 months – 10 years follow-up). A Mixed Model Analysis showed no significant effect of any of the measured angles on MTPM over time.

Since we are currently planning the last patients for the Inducible Displacement study-measurements, we were interested in the current State of the Art of Inducible Displacement research. Therefore, we are currently drafting a systematic review of 24 studies (selected from 247 abstracts) on Inducible Displacement in TKP. This review will be performed in collaboration with the department of Orthopedic Surgery of Dalhousie University Medical Centre, assuring two independent reviewers.

For our novel Inducible Displacement in TKP Study, we selected 30 out of approximately 100 patients with at least 7 years of follow-up from different ongoing TKP-studies in the LUMC. These patients are ranked based on the absolute difference in individual MTPM over the past three years. All 30 patients will perform the same set of 4 different tasks (i.e. weight bearing by standing on the affected leg only, the affected knee in 60 degrees flexion during weight bearing, internal and external torque), as well as 2 standard non-weight bearing RSA-examinations as reference. We will analyze the data to identify which (combination of) loading regime(s) will result in the highest amount of Inducible Displacement. Furthermore, we will investigate if there is an association between the amount of measured Inducible Displacement and the ranking based on the individual RSA-data. 20 of these 30 patients will also be asked to participate in our Gait Analysis in TKP Study. The results will be compared to the data of a healthy group of (age-matched) controls to analyze the effects of Total Knee Replacement on gait. We will also check if the patients with a higher MTPM-ranking have more pronounced gait differences.

DISCUSSION

In the currently available results we see no significant differences in performance between implant-designs or operation techniques. Although this is primarily good news of course, meaning that the chance of poorly designed implants or bad operation techniques being used on large groups of patients has been successfully diminished, it still doesn't solve the problem of individual aseptic loosening. Although up until now most Inducible Displacement studies found only small effects, in almost all of them the displacement was measured only a year after surgery in patient-groups mostly without complaints. We therefore hope to detect a more pronounced difference when we compare patients at different moments in their follow-up and with varying degree of migration over the last few years. If successful, this will lead to a novel method of quickly identifying the individual patients at risk of loosening and prevent overtreatment of patients with properly fixed implants.

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THE EPIDEMIOLOGICAL ASPECTS OF KNEE PROSTHETIC LOOSENING

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INTRODUCTION

Although radiostereometric analysis (RSA) has emerged as a highly accurate tool to detect implant migration after total knee arthroplasty (TKA) and predict loosening on a group level, for the individual patient, little is known about which migration profile is benign (i.e. merely part of a settling phase) and which migration profile is pathological. Furthermore, possible risk factors for loosening have been scantily reported and only in small, underpowered studies.

In the first part of this thesis, several randomised clinical trials were undertaken to explore gaps in both the performance of different modern TKA designs and in the analysis of short-term and long-term RSA studies (not further discussed below). In the second part of this thesis, these gaps were addressed by pooling individual participant data (IPD) of multiple RSA trials, subsequently increasing the power for subgroup analysis, aiming to assess different migration profiles and predisposing risk factors of tibial component loosening.

METHODS

Two meta-analysis studies were conducted using IPD meta-analysis of which we present preliminary results. The first gap was whether coronal alignment, specifically either deviation from neutral mechanical alignment or deviation from constitutional (natural) alignment, influences migration. Five long-term RSA studies conducted in the LUMC were pooled of which a total of 93 patients with a median follow-up of 11 years were included. Coronal alignment parameters were measured on pre- and postoperative full-leg standing radiographs and the constitutional (natural) alignment was determined for each patient by taking the preoperative medial proximal tibial angle and the lateral distal femoral angle, ignoring degenerative changes within the joint. Using a linear mixed-effects model analyses (correcting for study, age, gender, diagnosis and BMI), the effect of both preoperative constitutional alignment and deviation from mechanical alignment on tibial component migration were assessed.

In the second study, a large pooled dataset of 630 patients from 11 long-term RSA studies (median follow-up of 10 years), consisting of 4624 measurements enabled the opportunity to identify different migration profiles and assess predisposing risk factors of tibial component migration. The repeated RSA measurements were analysed using a linear mixed-effects model with age, gender, BMI, diagnosis, pre- and postoperative malalignment (>3° from neutral) and prosthesis characteristics as covariates, taking into account clustering of patients within studies.

RESULTS AND DISCUSSION

In study 1, we found mechanical varus malalignment to increase tibial component migration, while we found no association between migration and restoration of the constitutional alignment. In study 2, four different migration patterns were identified: (1) low initial migration, stable over time; (2) high initial migration with subsequent stabilisation; (3) continuous progressive migration; (4) progressive migration after a period of stability. Only postoperative alignment and use of uncemented components without a biologic mediator significantly influenced tibial component migration. This suggests that predisposing risk factors of loosening might not be patient specific, but mostly related to surgical skills and implant materials.

CONCLUSIONS

Pooling individual participant data of multiple RSA studies enabled the opportunity to evaluate the influence of coronal alignment and other possible predisposing risk factors on tibial component migration. Four distinct TKA migration profiles were identified. The found risk factors were only related to surgical factors and outcomes (i.e. postoperative deviation from mechanical alignment and using uncemented tibial components without biologic mediators enhancing bone ingrowth). Although IPD meta-analysis has many clinical and statistical advantages, the assessment of possible risk factors is limited to those that were measured in each of the individual studies.

DAY 3

PARALLEL PODIUM 3 – ANZORS Session

THE INFLUENCE OF ROTATOR CUFF TEARS ON SHOULDER JOINT CONTACT BEHAVIOUR AFTER REVERSE TOTAL SHOULDER ARTHROPLASTY

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INTRODUCTION
Reverse shoulder arthroplasty (RSA) is most commonly used in the treatment of end-stage rotator cuff tear arthropathy; however, failure in the form of early loosening of the glenoid component is the major factor limiting the longevity of current reverse shoulder implant designs [1]. Contact pressures and stresses produced at the glenoid component under dynamic muscle and joint loading directly influence wear and loosening observed in this component. In addition, rotator cuff tears are known to contribute significantly to abnormal joint loading and, therefore, to failure by wear and loosening of current total shoulder joint replacement (TSR) designs [2]. Currently it is not known whether certain rotator cuff tears are a contraindication for RSA. The aim of this study was to develop a 3-dimensional computational model of the shoulder after placement of a reverse shoulder prosthesis, and evaluate the influence of varying degrees of rotator cuff tears on joint contact behavior, including screw and implant stresses, as well as joint contact force.

METHODS
A 5-segment, 10-degree-of-freedom rigid-body musculoskeletal model of one male cadaveric upper extremity was developed in OpenSim. The model was actuated by 26 Hill-type muscle-tendon units, with muscle moment arms muscle paths matched to cadaveric measurements [3]. A virtual surgery was performed on this model to implant a trabecular metal reverse shoulder prosthesis (Zimmer Biomet). Simulations of abduction and flexion were then performed to evaluate muscle forces using this reverse shoulder anatomy model. A three-dimensional finite element model of the same shoulder was then developed (Abaqus, Dassault Systemes), which included trabecular and cortical bone geometry. A virtual surgery was performed to implant the Zimmer Biomet shoulder prosthesis into this model, with bone preparation and prosthesis placement guided by an orthopaedic surgeon. The muscle forces calculated with the rigid-body musculoskeletal model were applied to the finite element model during simulations of 10˚ abduction (elevation initiation) and 45˚ of abduction (mid-range of elevation). Simulations were repeated for the following conditions: (i) intact rotator cuff (ii) supraspinatus tear (iii) supraspinatus and infraspinatus tear (iv) supraspinatus, infraspinatus and subscapularis tear. For each simulation, screw, glenosphere and polyethylene liner peak von Mises stresses and stress locations were calculated.

RESULTS AND DISCUSSION
At 10° abduction, the highest joint contact stress concentration occurred at the glenosphere-socket interface with the entire rotator cuff intact (45.0 MPa). This stress magnitude decreased progressively with increase in rotator cuff tear. The superior glenoid baseplate fixation screw experienced substantially higher stresses than the inferior screw, for example, with the intact rotator cuff at 10° abduction, the peak superior and inferior screw stress was 42.3 and 7.6 MPa, respectively. The location of peak stresses in the glenosphere baseplate, glenosphere and humeral liner were invariant to rotator cuff tears. Peak contact stresses in the glenosphere were located more inferiorly at 10° abduction compared to those at 45° abduction (where they were oriented for compression), indicating the presence of greater prosthesis superior shear force during elevation initiation.

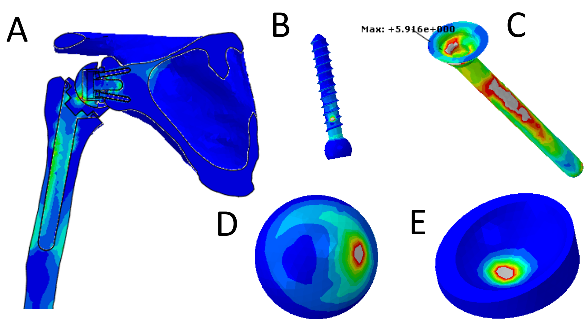

Figure 1: Representative stress distributions for the reverse TSR (A), superior base-plate fixation screw (B), prosthesis stem (C), glenosphere (D), and humeral liner (E).

CONCLUSIONS
Rotator cuff tears reduce the magnitude of the glenohumeral joint contact stresses overall, with the greatest shear stresses, and potential for loosening and failure, in early elevation. The superior glenoid baseplate screw incurs substantially higher stresses than that of the inferior screw, and may more at risk of loosening or fracture.

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IMPLANT-TENDON CONTACT PRESSURE IN AN ANATOMICAL TOTAL SHOULDER JOINT REPLACEMENT

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INTRODUCTION

One of the most common complications of shoulder arthroplasty is anterocranial migration and subachromial impingement due to rotator cuff failure and subsequent loss of the depressor strength [1]. One hypothesis for this complication is that the anatomical joint replacement impinges on the supraspinatus, which may ultimately produce stress concentrations and contribute to cyclic damage. To assess this hypothesis, the aim of this study was to develop a cadaveric model to simulate rotator cuff muscle loading and evaluate the contact pressure between the rotator cuff tendons and the prosthetic joint replacement component after implantation of the Lima SMR replacement, and compare the results to those in the native shoulder state.

METHODS

Eight fresh-frozen, male entire upper extremity specimens were harvested from human cadavers (mean age: 68 years). The skin and subcutaneous soft tissues proximal to the glenohumeral joint were removed and the proximal origins of each muscle detached. Loops of 5-Ethibond Suture were attached to tendons of each muscle and secured. Shoulder specimens were mounted onto a testing rig by potting the scapula in a hollow block with dental cement. Nylon lines attached to each rotator cuff tendon were passed through a backing plate. Physiological muscle force associated with each specimen's upper limb were determined for abduction using specimen-specific three-dimensional musculoskeletal models of the upper limbs [2]. Physiological muscle forces were calculated using the model for three shoulder joint positions: 10º, 45º and 90º of humeral abduction in the coronal plane, as well as the positions of full internal and external rotation at 45º of abduction.

For each shoulder joint positions, muscle forces calculated using the model were applied to the cadaver by means of simulated force application using a dead-weight system, while the humerus and glenohumeral joint was restrained with a clamp. Pressure sensitive Fuji film was placed underneath each rotator cuff tendon at the point where the tendon passed over and contacted the glenohumeral joint. The film was scanned and assessed to evaluate peak contact pressure. Experiments were performed on the native shoulder, and were repeated after total joint replacement surgery using the Lima SMR System. A one-way ANOVA was used to assess the influence of joint angle and surgery on contact pressures.

RESULTS AND DISCUSSION

Overall, both joint angle and shoulder joint replacement surgery had significant effects on the maximum contact pressure measured between the humeral head and all rotator cuff muscle tendons except teres minor ($p<0.05$), with maximum pressure increasing after surgery for all muscles (Table 1). The supraspinatus, one of the initiators of abduction, was found to decrease its contact pressure with the humeral head as abduction increased ($p = 0.008$), and demonstrated a significant increase in contact pressure at 45º of abduction with the humerus externally rotated relative to the native shoulder (mean difference: 0.36 MPa, 95% CI [0.19, 0.54], $p = 0.001$). The subscapularis and infraspinatus demonstrated significant increases in contact pressure after surgery, with subscapularis contact pressure significantly influenced by joint position

Table 1: Measurements of maximum tendon contact pressure between the native shoulder and shoulder after anatomical total joint replacement surgery at 10º, 45º and 90º of abduction. All data are mean pressure values (MPa). Significant differences in contact pressure with joint angle and surgery are indicated by 'a' and 'b', respectively.

	Natural			Anatomical			
	10º	45º	90º	10º	45º	90º	
Supraspinatus	1.1	0.8	0.4	1.6	1.0	0.4	a,b
Subscapularis	0.7	1.4	0.7	1.1	1.8	1.5	a,b
Infraspinatus	0.9	0.7	0.8	1.1	1.2	1.3	b
Teres Minor	0.4	0.4	0.5	0.3	0.4	0.4	

CONCLUSIONS

Greater contact pressure between the rotator cuff tendons and the humeral head of the Lima SMR anatomical joint replacement may present increased risk of tendon debridement post-operatively, particularly in that of the supraspinatus which is the major initiator of humeral elevation and develops comparatively large muscle force. The results suggest that decreasing the size of the humeral head component could reduce the magnitude of the tendon-implant contact pressure

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Clinical RSA Research Network

THE USE OF FIBERWIRE AND FIBERTAPE IN ROTATOR CUFF REPAIR

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INTRODUCTION

Rotator cuff repair surgery aims to re-establish the native tendon-bone footprint and pressure to permit re-establishment of the fibrovascular interface and promote tendon-bone healing. Recurrent tearing following rotator cuff repair has been shown to occur in 20-82% patients [1, 2], with suture pull-out through the tendon the predominant mode of failure. Braided FiberTape suture has been developed to increase repair construct contact pressure and area, however, the extent to which this occurs has not been quantified, and the biomechanical strength of this suture material is not well understood. The aim of this study was to evaluate contact pressure and area, ultimate tensile strength, gap formation and stiffness in double-row knotless repairs performed with FiberWire, and compare the results to FiberTape repair constructs.

METHODS

Sixty lamb infraspinatus tendons were harvested, and randomly allocated to three- and four-anchor knotless repairs performed using either No. 2 FiberWire or FiberTape (Figure 1). Thirty-two specimens were cyclically loaded for 200 cycles and tendon gap formation recorded. Loading to failure was then performed to evaluate construct ultimate tensile strength and stiffness. The remaining twenty-eight specimens were assessed for repair contact pressure and area using pressure-sensitive Fuji film.

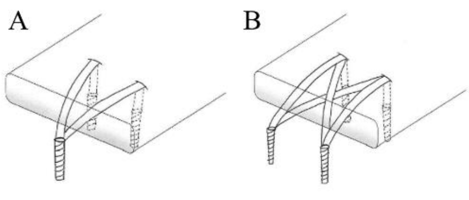

Figure 1. Diagram illustrating three-anchor (A) and four-anchor repair constructs (B) performed using FiberTape.

RESULTS AND DISCUSSION

There was a significantly greater average tendon contact pressure (mean difference: 0.064 MPa, p=0.045) and area (mean difference: 2.71 mm^2, p=0.030) in FiberTape repair constructs compared to those in FiberWire for the three-anchor repair. For the four-anchor repair, larger contact area was observed in the FiberTape construct compared to that in the FiberWire construct (mean difference: 2.94 mm^2); however, this difference was not significant (p>0.05). In both the three-anchor and four-anchor repairs using FiberTape smaller gap formation, greater stiffness and larger ultimate tensile strength was observed compared to equivalent repairs using FiberWire. Four-anchor FiberTape constructs had a significantly larger ultimate tensile strength (mean difference: 53.4 N, p=0.05) and stiffness (mean difference: 5.15 N/mm, p=0.049) compared to that of the four-anchor FiberWire constructs. The major outcome of this study was increased contact pressure, contact area and ultimate tensile strength observed in FiberTape repair constructs relative to those of traditional FiberWire.

CONCLUSIONS

FiberTape offers improved tendon-bone contact and strength properties in three- and four-anchor Suture-bridge constructs compared to those of FiberWire, and may ultimately improve tendon healing and construct longevity.

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A Novel Intramedullary Plating Technique for Reconstructing Proximal Humerus Fractures

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INTRODUCTION

Proximal humerus fractures are very common in the elderly [1]. The surgical outcomes for complex three- and four-part proximal humerus fractures tend to be poor [2]. This is due to loss of structural rigidity across the calcar region.

A lateral locking plate is the conventional method for proximal humerus reconstruction, with a calcar screw restoring some strength across the calcar region. However, the golden standard for restoring biomechanical function of the humerus is to combine an endosteal fibular allograft with the lateral locking plate [3].

Methods utilizing an intramedullary nail have been developed in an attempt to mimic this golden standard. These have resulted in some biomechanical improvements [4].

This study introduces a technique combining the traditional lateral locking plate with an intramedullary plate. Two variations of the new reconstruction technique are compared to an intramedullary nail and to the standard lateral locking plate reconstruction.

METHODS

24 humeri were used. A standardized calcar deficit was created in each humerus. Four different techniques were used to reconstruct the humeri (Figure 1): G1 - Lateral locking plate, G2 - Lateral locking plate with linked intramedullary plate, G3 - Lateral locking plate with unlinked intramedullary plate and G4 - Intramedullary locking nail. Six specimens were randomly allocated to each group.

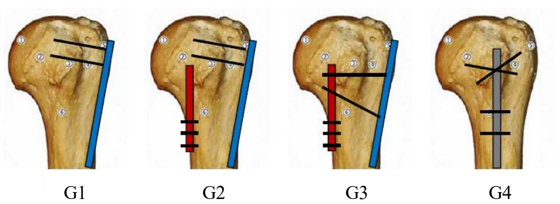

Figure 1: Schematic of the four different reconstruction groups

The specimens were loaded across the calcar deficit. A preload of 50N was applied for 10sec. Cyclic loading was then applied between this base load and peak loads increasing from 100N to 1000N in increments of 50N, with 50 cycles applied at each increment at a frequency of 0.3Hz.

The failure load was recorded. The vertical displacement across the calcar deficit at a load of 400N (before any failures occurred) was also compared.

RESULTS AND DISCUSSION

G3 had the highest average failure load of 710±139N, followed by G4 (610±290N), G2 (510±195N) and finally G1 (410±96N). There was no statistical significance between any of the groups (Figure 2).

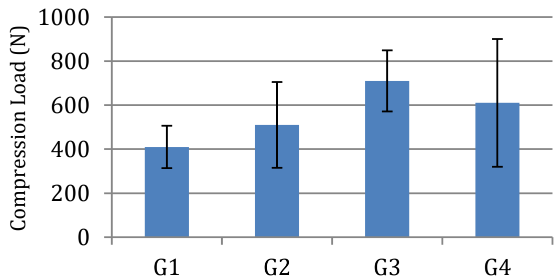

Figure 2: Average failure loads for the four different reconstructions.

CONCLUSIONS

The results indicate a trend for the new linked intramedullary plating technique to provide improved strength compared to the lateral locking plate alone. The results also suggest that the linked intramedullary plate may provide a good alternative reconstruction method compared to the intramedullary nailing technique. Further study will include a comparison of these new techniques with the use of the lateral locking plate combined with an endosteal fibular allograft.

ACKNOWLEDGEMENTS

All hardware was loaned for the purpose of the study by Depuy-Synthes.

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INSTRUMENTED KNEE PROSTHESIS WITH MWCNT/UHMWPE PIEZORESISTIVE SENSOR

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INTRODUCTION

Direct measurement of knee forces in total knee replacement (TKR) potentially provides crucial information to the researcher, clinician, and patient. The first instrumented knee was reported in 2004 [1]. This, and subsequent strain-gauge sensor technology iterations can measure integrated stress between the lower surface of the bearing and the tibial tray, but do not differentiate force measurements across the weight bearing surface, and therefore cannot detect suboptimal load distributions across the polyethylene bearing that may result in premature wear.

The aim of this study was to design a stress sensor that could be embedded at multiple locations in the polyethylene bearing without altering its mechanical properties. Multi-walled carbon nanotubes (MWCNT) were added to the ultra-high molecular weight polyethylene (UHMWPE) bearing material, to create piezoresistive sensors within the bearing. A two-stage compression moulding process was used to instrument the tibial insert with four hermetically sealed sensors. Resistance measurements during cyclic loading in a knee simulator showed cyclic changes with applied load.

FABRICATION OF INSTRUMENTED BEARING

Piezo-resistive MWCNT/UHMWPE sensors were fabricated through a three-stage process consisting of ultra-sonication, ball milling and compression moulding, with the concentration of MWCNT varying from 0.1 wt% to 10 wt%. Quasi-static cyclic compression test showed a decreasing trend of sensor resistance with increased loading [2].

A simplified 3D model total knee replacement system was formed, using compression moulding. For simplicity, a single-diameter sphere was used to shape the articulating surface of the insert. In the first stage, half of the tibial insert was moulded at 7 MPa and 170 °C. Four cylindrical holes of 8 mm diameter and 0.5 mm depth were milled from the lower half of the insert, allowing four MWCNT/UHMWPE sensor discs (sandwiched between copper film electrodes) to be formed. UHMWPE powder was inserted above the sensor and the first insert layer, to compression-mould the articulating surface. Resistance data from the four sensors was acquired through a custom-made data acquisition system.

RESULTS AND DISCUSSIONS

The compression moulding process was successful, resulting in an UHMWPE tibial insert with the sensors sealed inside, as shown in Fig.1. The cross-section view of a pressed UHWMPE disc showed that the sensor geometry was reasonably preserved during the hot-press, which guaranteed its piezo-resistive behavior. Cyclic running of the instrumented insert in the knee simulator (880 N constant-load) resulted in changing resistances, as illustrated in Fig.2.

Figure 1: UHMWPE insert with instrumented sensors. Cross-sectional view of fused sensors post- compression

Figure 2: Time-varying resistance of a sensor over 9 cycles.

CONCLUSIONS

The changing resistances of the MWCNT/UHMWPE sensors under cyclic loading proved its stress sensing capability. The two-stage compression moulding process was shown to be viable for hermetically sealing the sensors within the tibial insert, while still being able to bear the load.

ACKNOWLEDGEMENTS

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QUANTIFICATION OF BONE MICROARCHITECTURE DAMAGE OF A PRESS-FIT FEMORAL KNEE IMPLANT

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INTRODUCTION

Press-fit fixation of prostheses is obtained thanks to the inside dimensions of the implant being undersized with respect to the bone cuts created intra-operatively. However, during the implantation process, high compressive stresses are generated within the bone and at the implant-bone surface, which might permanently damage the bone. The amount of damage is still unknown.

The aim of this study was to quantify, using high-resolution peripheral quantitative computed tomography (HR-pQCT, 61µm/voxel), permanent bone deformation in bone microarchitecture due to press-fit femoral knee implants.

METHODS

Specimens: Six human cadaveric femora (age 85 ± 3 years, fresh-frozen) were obtained. The bone specimens were thawed at room temperature and an experienced orthopaedic surgeon made bone cuts following normal surgical procedure using standard intramedullary instrumentation.

1st HR-pQCT scan: The entire resected distal femur specimens were scanned with HR-pQCT (XtremeCT II, SCANCO Medical AG, Bruettisellen, Switzerland) and all cross-section images reconstructed at 60.7µm isotropic voxel size.

Implant fitting: The bone specimens were then fitted (five size 5 implants, one size 3) with a cementless Sigma® cruciate retaining femoral knee implant with porous surface coating, Porocoat® (DePuy Synthes Joint Reconstruction, Leeds, UK). After implantation, the implants were split through the condyles using a diamond-blade cutting machine, for component removal without causing additional bone damage.

2nd HR-PQCT scan: The bone specimens were then rescanned with HR-pQCT, with the same settings as in scan 1.

Image Registration: Software DataViewer (Skyscan-Bruker) was used to perform 3D image registration of the pre- and post-implantation cross-section images.

Image Analysis: For each specimen, volumes of interest (VOI) were selected using CT Analyzer (Skyscan-Bruker) to separately examine the posterior medial and lateral condyle. Each VOI included 10mm of depth from the first posterior cross-section image (coronal plane) containing the entire condyle in the pre-implantation data set as reference. The bone volume fraction (BV/TV) for the pre- and post-implantation images and their ratio (BV/TV_{post} / BV/TV_{pre}) were calculated, slice by slice at increasing depth [1] in posterior-anterior direction and plotted in a graph (Fig.1a).

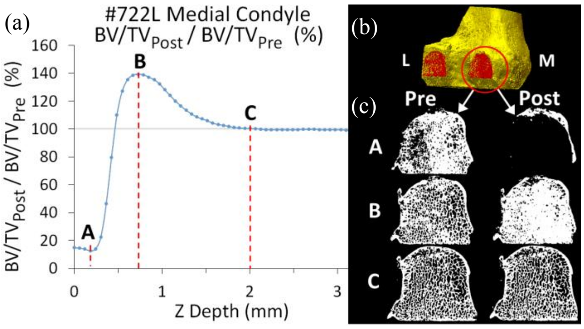

Figure 1: (a) BV/TV_{post} / BV/TV_{pre} ratio vs. posterior-anterior depth; (b) HR-pQCT 3D posterior view, femur condyles, damaged/removed bone in red color; (c) HR-pQCT coronal cross-section images, pre- and post-implantation, medial condyle, at increasing coronal depth showing: **A** peak bone removal, **B** peak compaction, **C** correspondence

RESULTS AND DISCUSSION

The "$BV/TV_{post/pre}$ ratio vs. depth" graphs (Fig. 1) showed, consistently among the six femurs, three consecutive points of interest, differing significantly in $BV/TV_{post/pre}$ ratios and depth among them ($p<0.05$, Friedman and Wilcoxon signed rank tests), indicating: bone removal ($BV/TV_{post/pre}$ ratio <100%), compaction ($BV/TV_{post/pre}$ ratio >100%) and correspondence ($BVTV_{post/pre}$ ratio= 100%).

On average, peak bone removal (A, $BV/TV_{post/pre}$ ratio= 29±20%, mean±SD) occurred at 0.1±0.1mm depth, peak bone compaction (B, $BV/TV_{post/pre}$ ratio= 143±32%) at 0.9±0.5mm, whereas correspondence between pre- and post-implantation (C, $BV/TV_{post/pre}$ ratio= 98±3%) at 2.1±0.5mm (Fig.1c).

CONCLUSIONS

High-resolution 3D imaging enabled us to detect, classify and volumetrically quantify permanent bone damage occurring during the press-fit implantation process. The apparent damage occurs up to 2 mm in depth, first with bone removal including abrasion, followed by densification and then by no changes (correspondence). Quantifying microarchitectural bone damage is important for gaining insight into the extent of damage/plastic bone deformation that occurs after placing a femoral press-fit implant. This data can be used, including in combination with digital volume correlation, to inform surgeons, manufacturers, advance computational models and compare bone response to different implant surface coating or press-fit values.

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DEEP KNEE FLEXION CAPTURED USING A 2D-3D IMAGE REGISTRATION PROCESS DISPLAYS DIFFERENT ARTHROKINEMATICS IN OLDER MEN AND WOMEN

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INTRODUCTION

Sex differences in tibio-femoral arthrokinematics have rarely been studied beyond 120° and not in older people [1]. Technological advancement in medical imaging and registration has recently enabled accurate and non-invasive capturing of knee movement in six degrees-of-freedom. This study aimed to investigate differences in male and female tibio-femoral arthrokinematics during kneeling in non-arthritic older adults.

METHODS

This cross-sectional observational study was nested within a larger study called PICKLeS: a prospective imaging study of arthroplasty kinematics compared to osteoarthritis and healthy ageing. A 2D-3D image registration technique was used to analyse the *in vivo* tibio-femoral joint in six degrees-of-freedom. We analysed 15 healthy males and 15 healthy females above the age of 45. Their knees were imaged using computed tomography and then captured kneeling using single plane fluoroscopy. A 2D-3D image registration technique was used to analyse the *in vivo* tibio-femoral joint. Clinical and function tests ensured participants were healthy. We used linear mixed models for statistical analysis.

RESULTS AND DISCUSSION

We aimed to explore the effect of sex on the pattern and magnitude of tibio-femoral arthrokinematics during flexion into, and also for extension out of, deep kneeling.

It was observed that males had 4.5° (95% CI = -7.55, -1.49) more tibial internal rotation than females rising out of kneeling (Figure 1), however there was no difference kneeling into flexion ($p > 0.05$). Males and females also demonstrated different anterior/posterior pattern profiles in both kneeling directions ($p < 0.05$), however no clinically significant difference in the magnitude of movement was observed. Males displayed 3.1 mm (95% CI = 1.00, 5.25) more distraction into flexion. There were no sex differences found for abduction/adduction, medial/lateral translation and maximum flexion angles ($p > 0.05$).

It was hypothesised that women would internally rotate the tibia more than men given that women typically display less torsional knee stiffness compared to men [2,3]. We believe our results reflect sex dependent motor control strategies, given that the difference in magnitude of internal/external rotation occurred only as participants ascended out of deep kneeling.

Our results regarding internal/external rotation differ to those by Leszko, who reported less internal rotation in males compared to females [1]. On the other hand, both Feng and Varadarajan reported no sex effect on the magnitude of internal/external rotation during flexion [4,5]. However, all three authors examined different functional activities, whereas this study was the first to examine a weight bearing kneeling activity in older adults. By the same token this study was also the first to use pairwise analysis to determine the effect of sex on kinematic pattern and magnitude of movement over the entire flexion arc.

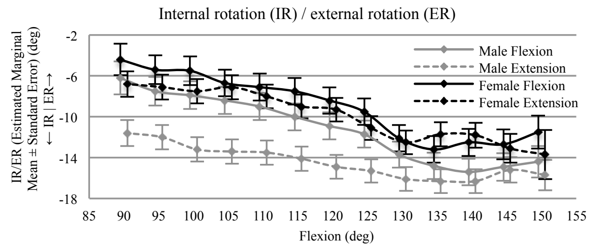

Figure 1: Internal/external rotation as a function of flexion into and out of deep kneeling by sex.

Given that the assessor was not blinded during testing or registration, bias may have been introduced to the study.

CONCLUSIONS

Males demonstrated more tibial internal rotation rising out of kneeling, which is new information regarding tibiofemoral arthrokinematics in older adults.

By using the most accurate single-plane fluoroscopy technique available for measuring arthrokinematics in six degrees-of-freedom, this study demonstrated a safe and non-invasive means of capturing three-dimensional joint movement.

ACKNOWLEDGEMENTS

This study was funded by Biomet Pty Ltd and the Canberra Hospital Private practice Trust Fund.

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No investigator or member of research staff received a personal financial benefit from this study.

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The study was funded by Biomet Pty Ltd and the Canberra Hospital Private practice Trust Fund. An agreement was signed that precluded Biomet from prohibiting any results from being published.

DAY 3

PARALLEL PODIUM 3 – RSA Session

PRECISION AND ACCURACY OF MODEL-BASED RADIOSTEREOMETRIC ANALYSIS OF THE GLENOID COMPONENT IN REVERSED TOTAL SHOULDER ARTHROPLASTY

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INTRODUCTION

Reversed Total Shoulder Arthroplasty (RTSA) introduces major biomechanical changes to the shoulder joint, and glenoid component loosening is one cause of failure. Radiostereometric Analysis (RSA) is the golden standard to measure stability of implants *in vivo*. Within RSA, models can be created by either reversed engineering (RE) or by large marker models (LMM). The geometrical shape of the implant, the marking of landmarks and positioning of markers has great influence on the precision and accuracy of RSA measurements. The stability of the glenoid component of RTSA has not been analyzed with RSA before, and therefore the precision, accuracy and whether it is a suitable method is unknown. The study aimed to answer the following questions: 1) What is the accuracy of model-based RSA of the glenoid component? 2) What is the precision of model-based RSA with LMM and RE on the glenoid component of RTSA in patients? 3) Is model-based RSA suitable to measure the stability of the glenoid component of RTSA?

METHODS

We attached the glenoid component to a micrometer on an acrylic glass phantom resembling the scapula with 10 implanted markers. We performed 10 orthogonal translations along each of the x-, y- and z-axis, and 6 rotations around each of the x-, y- and z-axis. Accuracy is expressed as the mean difference (95% confidence interval) between the values of the micrometer and the measured values. Precision analysis was based on 12 double examinations of the phantom and 19 double examinations in 11 patients from an ongoing RCT. An RE model of the Delta Xtend® glenoid component (Metaglene®, Glenosphere®), from Depuy Synthes Institute, was obtained by laser scanning. All precision analysis was performed with RSAcore® software, with the modalities Large Marker Model and RE. Scenes with Condition Number >120 and Mean Error >0,5 were excluded. Precision was expressed as 1,96*standard deviation (SD) of the differences between double examinations. We placed the patient in different positions (hip or shoulder) to achieve different projections of the component.

RESULTS AND DISCUSSION

9 out of 14 double examinations in the 6 patients placed in the hip position were excluded due to poor implant and marker visualization, or CN>120; and therefore hip positioning was abandoned. Accuracy ranged from -0,007 (-0,03, 0,02) to -0,012 (-0,05, 0,02) mm for translations, and -0,057 (-0,11, -0,01) to -0,29 (-0,58, 0,01)° for rotations. Clinical precision for translations ranged from 0,13 to 0,25 mm using RE, and 0,18 to 0,34 mm using LMM. For rotations, the precision ranged from 0,20 to 0,7° for RE, and 0,82 to 1,8° for LMM. Phantom precision for all translations and rotations were better than 0,5 mm and 1° using RE, and 0,24 mm and 1,4° using LMM.

CONCLUSIONS

RE models of the glenoid component is preferable to LMM for migration analysis. The precision and accuracy of Model-based RSA for the glenoid component in Reversed Total Shoulder Arthroplasty, is comparable to results in hips and knees. RSA is a suitable tool to measure stability of the glenoid component, but patient positioning is crucial.

ACKNOWLEDGEMENTS

The study has received funding from Sophies Minde Ortopedi AS, which is a subsidiary of Oslo University Hospital HF.

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1. The study has received funding from Sophies Minde Ortopedi AS, which is a subsidiary of Oslo University Hospital HF. There is no other relation between the authors and Sophies Minde.

2. A commercial entity, Orthomedic, supplied DePuy Synthes Delta Xtend implant components for construction of a phantom and RE. There are no obligations connected with this.

CT-BASED PROSTHESIS MIGRATION MEASUREMENTS: A PILOT STUDY

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INTRODUCTION

Currently, Roentgen Stereophotogrammetric Analysis (RSA) is considered the preferred method to measure implant migration. This method involves the insertion of tantalum beads in the bone and analysis of calibrated stereo roentgen images. As a result, RSA is a relative complex method that is only used in specialized hospitals.

Recently, it has been shown that migration can also be measured with Computed Tomography (CT) [1]. The advantage of CT-based measurements is that bone markers are not required and that the special stereo roentgen equipment can be replaced by a standard CT-scanner. The most important drawback of CT compared to RSA [2] is its higher radiation dose. However, with the recent advancements in ultra-low dose CT scanning, this drawback may become less relevant.

Therefore, the goal of this study was to develop and validate a CT-based prosthesis migration measurement system and to compare the accuracy and precision of the CT-based measurements with RSA.

METHODS

Baseline and follow-up CT scans were compared by performing two separate affine transformations: 1) by matching the bones only; and 2) by matching the prosthesis only. The transformations were obtained by image registration with a mask for the bone and the prosthesis, respectively. From these two transformations the migration can be calculated [1]. MeVisLab (V2.8.1, MeVis Medical Solutions AG, Germany) was used for image processing; ElastiX was used for image registration [3]; and Matlab (V.R2016b, MathWorks, US) for migration calculations.

To determine the precision of the method, two tibia prostheses were each rigidly cemented in a cadaveric proximal tibia bone. Each tibia was scanned 10 times in different clinically relevant poses by a Toshiba Aquillion ONE CT scanner (pixel spacing: 0.35x0.35mm, slice spacing 0.25mm, slice thickness 0.5mm). Migration was calculated between all CT dataset combinations. As the prosthesis did not move with respect to the bone, the measured migration provides the precision of the method.

To determine the accuracy, a tibia prosthesis was moved by means of a micromanipulator with respect to a saw-bone in 7 steps (between 0.1 and 1.5mm) for each of the three directions and rotated in 3 steps (between 0.5 and 1.5 deg.) about its longitudinal (y) axis. These 28 CT datasets were made using the same CT scanner and imaging protocol. Accuracy was calculated by comparing the migration results with the gold-standard values of the manipulator.

The accuracy experiment was repeated in a standard uni-planar RSA setup and migration was calculated using Model-based RSA (V4.11, RSA*core*, LUMC, Leiden, The Netherlands).

Table 1: Accuracy of CT- and RSA-based migration (N=24).

	Accuracy: Mean (Standard Deviation) (mm/deg.)					
	Tx	**Ty**	**Tz**	**Rx**	**Ry**	**Rz**
CT	0.00 (0.08)	0.10 (0.12)	0.01 (0.05)	-0.04 (0.08)	-0.01 (0.09)	0.02 (0.06)
RSA	-0.03 (0.07)	0.01 (0.02)	-0.02 (0.05)	-0.01 (0.04)	0.01 (0.14)	0.01 (0.03)

RESULTS

For translations, the worst precision, defined as standard deviation of the migration results of the cadaver experiment, was 0.01 mm in the longitudinal (Ty) direction and for rotations 0.04 deg. for medial lateral (Rz) tilting.

For CT, the worst accuracy for translations was 0.12 mm in Ty direction (perpendicular to the slice direction), and 0.09 deg. around the Ry axis. For RSA, the worst accuracy for translations was 0.07 mm in the Tx direction and 0.14 deg. about the Ry axis for rotations (Table 1).

CONCLUSIONS

These pilot experiments show that CT has good potential to provide migration results that are similar in accuracy and precision as Model-based RSA. Before CT can replace RSA in clinical studies to measure prosthesis migration, it is necessary to significantly reduce the radiation dose for CT and clinical validation studies are needed to estimate the effect of CT scanner variations and bone remodeling on the registration accuracy.

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ACCURACY AND PRECISION OF RSA IN THE LOW-DOSE EOS IMAGER: A PHANTOM MODEL STUDY

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INTRODUCTION

The EOS imager (EOS Imaging, Paris, France) is a low radiation dose biplanar X-ray slot scanner that has demonstrated reduced radiation dose of 6-9 times compared to conventional radiography. This imager scans patients in a weight-bearing position, provides calibrated three-dimensional information on bony anatomy, and may potentially limit the radiation exposure during serial RSA studies. The EOS imager has a larger pixel size than current digital RSA systems and the vertical translation of its scanning X-ray head may impact the accuracy and precision of the RSA technique. This accuracy and precision phantom study used a slipped capital femoral epiphysis (SCFE) model, a hip condition where the epiphysis slips at the growth plate in early adolescence. The ability to assess relative stability of the fixation may allow tailored post-operative rehabilitation protocols and predict treatment failure. All tests conducted in both a calibrated EOS and a standard uniplanar set-up.

METHODS

A Sawbones® severe slip SCFE femur phantom (Pacific Research Laboratories, Vashon Island, WA) was cut across the femoral head and was implanted with a 7.3 mm-diameter, 45 mm-long fully threaded stainless steel cannulated fixation screw (Synthes, West Chester, PA). A total of 11 1mm RSA markers were implanted, 4 in the epiphysis, 7 in the metaphysis. For accuracy assessment, inter-body translations between 0.1 and 2mm and rotations between 0.17 and 4° were applied to the phantom with micrometer driven staging, and 95% prediction intervals calculated. Precision was assessed by comparing radiographs taken at various locations within the imaging volume without intra-phantom movement, and the 95% confidence interval calculated. Analysis for the calibrated EOS radiographs was conducted with a custom Matlab code. Standard RSA suite radiographs were analyzed in Model-Based RSA 3.41 software (RSAcore, Leiden, The Netherlands).

RESULTS AND DISCUSSION

Acceptable condition numbers of 67 for the epiphysis and 26 for the metaphysis were obtained. Accuracy values were similar between the EOS (±0.04, 0.03, and 0.09mm for x, y and z translation; ±0.20, 0.14, and 0.2° for R_x, R_y, and R_z rotation) and the standard uniplanar RSA system (±0.05, 0.03, and 0.07mm and ±0.18, 0.16, and 0.14°) but were statistically different ($p<0.01$). Bland-Altman analysis found the mean difference in accuracy between the modalities was less than 0.04mm and 0.11°, with upper limits of agreement below 0.13mm and 0.26°.

Only two precision measurement tests were statistically different between imagers, and both were more precise in the EOS. Even displaced by 10cm from the isocenter, the EOS precision was ±0.05, 0.01, and 0.03mm, and ±0.50, 0.47, and 0.13°. Placing the phantom at a 45° angle did not increase the error. However rotating the phantom 15° around each of the axes did significantly increase the error in both systems (uniplanar: ±0.11, 0.37, and 0.25mm, and 0.30, 0.31, and 0.09° and EOS:±0.12, 0.46, and 0.15mm, and 0.39, 0.59 and 0.13°). The increase in both modalities points to possible bead placement issues in the small epiphyseal volume.

CONCLUSIONS

Within the SCFE model, the EOS exhibited comparable translational and rotational accuracy and precision to the standard technique. This phantom study demonstrated an RSA accuracy and precision higher than ±0.09mm and ±0.05mm respectively for translations and ±0.20° and ±0.36° for rotations in the EOS modality while the standard application of RSA displayed an accuracy and precision higher than ±0.07mm and ±0.05 mm in translation and ±0.18° and ±0.32° in rotation respectively when centered in the imaging space. RSA combined with low radiation EOS imaging has potential for monitoring young post-operative SCFE patients.

ACKNOWLEDGEMENTS

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   Halifax Biomedical Inc. (Mabou, Nova Scotia) and EOS Imaging (Paris, France) are Key Project Collaborators, contributing expertise and matching funds to the Atlantic Canada Opportunities Agency project (grant #199377) which is funding this study.

VALIDATION OF RADIOSTEREOMETRIC ANALYSIS IN SIX DEGREES OF FREEDOM FOR USE WITH REVERSE TOTAL SHOULDER ARTHROPLASTY

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INTRODUCTION

Since its approval by the Health Canada in 2003, and the US Food and Drug Administration in 2004, reverse total shoulder arthroplasty (RTSA) has grown to account for over 30% of all shoulder procedures, with its prevalence expected to increase [1]. This indicates a need for evaluation of implant fixation, as there are limited studies considering long-term survival of the joint replacement.

Radiostereometric analysis (RSA) can provide valuable information regarding the fixation and migration patterns of different RTSA implants prior to widespread distribution. Before clinical evaluation, however, a phantom study needs to be completed in order to validate the RSA system for use with the implant in question [2].

The objective of this study was to determine the accuracy and precision of RSA for RTSA in six degrees-of-freedom (DOF) using a phantom study.

METHODS

A plastic model of the shoulder bones was fitted with a RTSA implant set. Tantalum beads (⌀0.8 mm) were inserted in the bone surrounding the glenosphere (n = 6) and humeral stem (n = 7) at the approach angles available during surgery. A 6 DOF translation and rotation stage was used to change the pose of the phantom through fifteen known increments in translation, and twelve increments in rotation (0.02-5.00 mm and 0.1-6.0°), along each of the 6 axes. At each pose, two x-rays were taken simultaneously from different foci. MBRSA software (RSACore, Leiden, Netherlands) was used to locate the implant in 3D space and calculate the apparent migration at each increment (Fig. 1).

The accuracy and precision of the movement between the glenoid and humerus were assessed using beads vs. beads (B/B), model vs. beads (M/B), and model vs. model (M/M) measurement methods. Accuracy and precision were defined as the standard deviation of the average error between increments, and between double exposures, respectively.

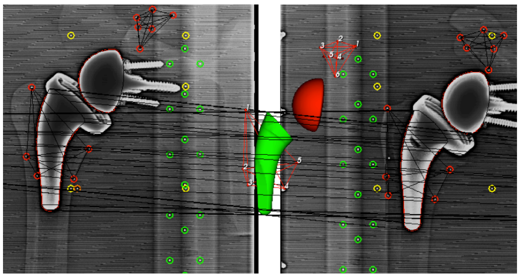

Figure 1: The model-based RSA environment showing the tantalum beads inserted in the phantom (red circles) and the implants' surface models.

RESULTS AND DISCUSSION

Accuracy ranged from ±0.047 to ±0.096 mm and ±0.109 to ±0.142° (B/B); ±0.037 to ± 0.096 mm and ±0.151 to ±1.091° (M/B); and ±0.042 to ± 0.154 mm and ±0.328 to ±0.536° (M/M). Precision ranged from ±0.056 to ±0.091 mm and ±0.050 to ±0.134° (B/B); ±0.033 to ±0.082 mm and ±0.037 to ±1.115° (M/B); and ±0.039 to ±0.136 mm and ±0.144 to ±0.574° (M/M). Implant symmetry was identified as a contributing factor to the lower limits of accuracy and precision in rotation, predominantly along the axis of internal-external rotation.

CONCLUSIONS

The accuracy and precision of RSA for RTSA are comparable to the accepted values for the hip and knee, ranging from 0.05 – 0.50 mm and 0.15 – 1.15° [3]. This study provides a foundation for future clinical studies by determining the limits of RSA system performance.

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ACCURACY OF A CEMENTED VS UNCEMENTED PHANTOM STUDY OF A HINGED TYPE KNEE REVISION SYSTEM WITH MODEL BASED RSA

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INTRODUCTION

Several RSA studies are performed to investigate the superior implant fixation technique (for example, uncemented or cemented) for all types of implants. For determining the accuracy of the set-up, a phantom study should be performed. To our knowledge, it has never been investigated before whether the type of implant fixation technique used in such a phantom study can influence the accuracy results.

Since we planned to perform a phantom study for an RSA study with a cemented implant, we decided to perform two subsequent phantom experiments with the same implant and sawbone. We aimed to investigate differences in accuracy between an uncemented and cemented hinged type knee revision system. We hypothesized a higher pose difference (PD) for the cemented component due to a contour detection with less contrast.

METHODS

First, the LEGION HINGE KNEE (HK) SYSTEM (Smith & Nephew, Memphis, USA) was implanted uncemented in a sawbone, and 10 1-mm tantalum markers were fixed to the exterior of the femur and tibia. Images for 9 extreme supine positions were made. Subsequently, the implant was cemented at the operating theatre and the protocol was repeated.

Model-based RSA version 4.10 (RSAcore, Leiden, The Netherlands) was used with CAD-models of the implant. For both the uncemented and the cemented implant, paired migration was calculated between the 9 positions to calculate the accuracy, with default settings in MB-RSA for both fixations. Reported outcomes are translation (T) in mm, rotation (R) in degrees, maximum total point motion (MTPM) in mm, total translation (TT) in mm, total rotation (TR) in degrees and the PD between the actual contour and the virtual contour in mm (contour percentage is set at 10%).

RESULTS AND DISCUSSION

The measured translations and rotations were comparable between the cemented and uncemented prosthesis (Table 1). The PD for the femur component showed a trend towards a higher value for the uncemented component (p=0.059) (Figure 1). PD for the tibia component was not significantly different (p=0.35).

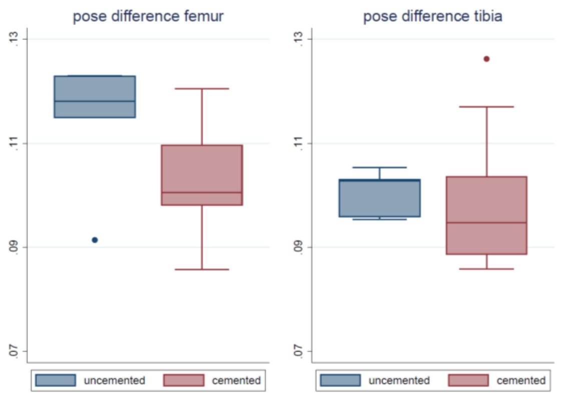

Figure 1: Pose differences (mm) femur and tibia component

CONCLUSIONS

Although a trend towards a higher pose difference for the uncemented femur was found, this did not influence the accuracy of the phantom experiments.

ACKNOWLEDGEMENTS

We would like to acknowledge Smith & Nephew for providing the implant for the phantom study, Dong Tran from the radiology department of the Sint Maartenskliniek for taking the RSA images, and Lennard Koster from RSAcore for his help with the interpretation of the results.

Table 1: Accuracy, for each component the standard deviation of the paired migrations is reported.

Component	Tx	Ty	Tz	Rx	Ry	Rz	MTPM	TT	TR
Femur uncemented	0.10	0.03	0.10	0.24	0.24	0.24	0.20	0.09	0.23
Femur cemented	0.13	0.07	0.19	0.29	0.47	0.16	0.30	0.12	0.22
Tibia uncemented	0.17	0.10	0.11	0.24	0.31	0.24	0.26	0.11	0.25
Tibia cemented	0.10	0.10	0.14	0.18	0.12	0.13	0.15	0.10	0.14

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1. A commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

   This phantom experiment was part of a clinical study which is financially supported by Smith & Nephew (payments to hospital, research department).

PRECISION OF AUTOMATED GPU ACCELERATED ANALYSIS OF DYNAMIC RSA IN THE HIP

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INTRODUCTION

Dynamic radiostereometric analysis (dRSA) allows the study of the three-dimensional *in-vivo* movements of bones, which can provide insight in the kinematics relevant for both diagnostics and the development or validation of new implants. Current marker-based RSA (MM) requires the insertion of beads and therefore cannot be used for pre-operative analysis. Traditional model-based RSA (MBM) analysis requires manual analysis, which is time consuming and operator dependent. When bone models from CT are used, the analysis is limited to the contours of the bones and does not use the density information available from the CT [1].

In this study, we perform analysis using an automated GPU accelerated digitally reconstructed radiograph (DRR) based method that uses both the bone edges and the internal bone structure and density differences to determine the position of the bones in each frame of the dynamic recording.

The aim was to validate the precision of the DRR based analysis with respect to MBM using MM as gold standard.

METHODS

Seven human cadaveric hemipelvis were CT-scanned and bone models were created using an automated method [2]. Tantalum beads were inserted in the proximal femur and pelvis. RSA recordings were acquired at 5 frames/sec during flexion, adduction and internal rotation. All images were analyzed by DRR, MBM, and MM. The first frame of the DRR analysis was manually initialized. A multi-resolution with global and local optimizer was used. Migrations were calculated with respect to MM in 6 degrees of freedom. Precision was assessed as systematic bias (mean difference) and random variation (Pitman's test) with respect to MM as gold standard.

RESULTS AND DISCUSSION

In total 285 dRSA images were analyzed. Systematic bias for MBM and DRR with respect to MM in translations (<0.016mm) and rotations (<0.012°) were approximately zero and no difference between MBM and DRR ($p>0.65$) was found (Figure 1). Random variation was lower ($p<0.00$) in all degrees of freedom for DRR compared to MBM (Table 1).

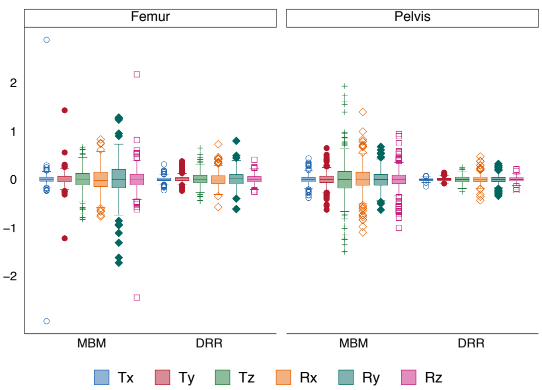

Figure 1: Box plots of translations and rotations for the femur and pelvis for MBM and DRR with respect to MM.

CONCLUSIONS

The systematic bias was approximately zero for both MBM and DRR based analysis. Precision for DRR was significantly better compared to MBM. Since the DRR analysis is automated and does not require markers, the method can be used for analysis of large dynamic pre- and post-operative studies that were previously not possible.

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Table 1: Overview of the precision (1.96*SD) for translations and rotations for both methods for the femur and pelvis.

	Femur						Pelvis					
Method	**Tx**	**Ty**	**Tz**	**Rx**	**Ry**	**Rz**	**Tx**	**Ty**	**Tz**	**Rx**	**Ry**	**Rz**
DRR	0.11	0.15	0.29	0.29	0.33	0.19	0.05	0.06	0.16	0.19	0.19	0.12
MBM	0.50	0.31	0.46	0.52	0.75	0.53	0.20	0.30	0.86	0.58	0.39	0.46

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   Partners from Nordic Roentgen Technique, Aarhus University and Aarhus University Hospital, received a grant from the Innovation Fund Denmark (grant# 69-2013-1), a public fund, to conduct the AutoRSA development project.

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   NONE

ASSESSMENT OF ACCURACY OF RADIOSTEREOMETRIC ANALYSIS(RSA) IN PHANTOM EXPERIMENTS USING A SINGLE ROBOTIC X-RAY TUBE COMPARED TO CONVENTIONAL RSA

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INTRODUCTION

Radiostereometric analysis (RSA) of implant migration in orthopaedics is routinely conducted with two synchronized X-ray tubes. The use of two special customized ceiling-mounted X-ray tubes normally is associated with a big investment. The usage of a combination of one stationary and one mobile X-ray tube could be very time consuming. Thus, the use of a single programmable robotic Roentgen tube with a time difference of just a few seconds for picture acquisition could be a less expensive and time-saving alternative. The objective of this trial was to evaluate RSA accuracy of such equipment in a phantom study.

METHODS

Radiographs were taken using one fixed programmable robotic X-ray tube (Multitom Rax®, Siemens Healthcare GmbH , Forchheim, Germany). Under the guidelines for RSA [1,2], uniplanar technique was used to perform RSA examinations. The X-ray tube with a setting of 81 kV and 3.5-4.2 mAs was positioned 1.40 m above the calibration box Umea Cage 43 (RSA BioMedical Innovations AB, Umea, Sweden) with an angle of approximately 18° to the perpendicular through the center of the implant. Translations of three axes (x, y and z) were performed sequentially in steps of 0.02 mm, 0.05 mm, 0.1 mm, 0.2 mm, 0.5 mm, 0.9 mm, and 1.5 mm for eight times in anterior-posterior projection of the tibial component of a total knee arthroplasty implant (BPK-S Peter Brehm, Weisendorf, Germany). After picture acquisition, the programmed robotic tube and the robotic detector automatically changed positions to the other side of the perpendicular in the same angle. The second picture was recorded after approximately 5 seconds. Radiographs were analyzed via RSA software MBRSA 4.1 (MedisSpecials, Leiden, Netherlands). Accuracy was calculated according to the formula [3]: Accuracy=$1.96 \times \sqrt{\sum d^2 / 2n}$. The data were compared to previously acquired data about accuracy of a standard RSA set-up with the same implant, projection and procedure.

RESULTS AND DISCUSSION

The mean, SD, and accuracy of the measured vector of translations for the in vitro experiment with a phantom were 0.081 mm, ±0.133 mm and 0.173 mm for model-based RSA and 0.071 mm, ±0.110 mm and 0.143 mm for marker-based RSA, respectively. The comparative data from previously standard model-based RSA phantom study was 0.070 mm, ±0.098 mm and 0.128 mm, respectively. The use of a single automatical mobile X-ray tube had no clinically significant influence on accuracy of RSA migration measurements in phantom experiments.

CONCLUSIONS

The use of the Multitom Rax® provides results comparable to standard RSA in phantom experiments. However, the influence of inevitable patient movements caused by breathing or arterial pulsations on RSA accuracy has to be analyzed in future experiments.

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Do you have a conflict of interest to declare?

YES
All experiments were financed by Siemens Healthcare GmbH, Forchheim, Germany. The co-author Andreas Fieselmann is an employee of Siemens.

HIGH PRECISION AND ACCURACY OF MODEL-BASED RSA IN TOTAL WRIST ARTHROPLASTY

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INTRODUCTION

Radiostereometric analysis (RSA) has never been used in total wrist arthroplasties. We investigated (1) the precision of model-based RSA using both phantom and clinical double examinations, (2) the precision of different bone marker distributions in a phantom model, and (3) the accuracy of model-based RSA in two different wrist arthroplasties.

METHODS

Reverse engineered models of the Remotion® and Motec® total wrist arthroplasties were obtained by laser scanning. Precision and accuracy of the radial and carpal/metacarpal component of each arthroplasty were analysed with regards to translation and rotation along the three cardinal axes. Precision was analysed from 10 phantom and 30 clinical double examinations in each arthroplasty, and was expressed by a repeatability coefficient as 2 x standard deviation of the differences between double examinations. Levine`s test for equality of variances was used to examine the difference in precision between different bone marker configurations. Accuracy was tested in a phantom model with the implants attached to a movable micrometer, and was defined as the mean difference between measured and true migration. For translations a ”zero migration” stereoradiograph was first obtained, followed by 0.005, 0.1, 0.2, 0.4, 0.8, 1.5, 2.0, 3.0, 4.0 and 5.0 mm translations along all three axes. For rotations a ”zero migration” stereoradiograph was obtained, followed by 0.08, 0.2, 0.4, 0.6, 1.0. 2.0. 3.0, 4.0 and 6.0 degrees of rotation.

RESULTS AND DISCUSSION

In the phantom model the repeatability coefficient for precision ranged from 0.03 to 0.14 mm and from 0.18 to 1.56°, and in patients from 0.06 to 0.18 mm and 0.33 to 2.23°. Translation along the out of plane Z axis and rotation about the out of plane Y axis were least precise. Fewer than four bone markers resulted in an inferior precision, and due to the problems of visualizing bone markers in the thin wrist bones we recommend placing at least 6 markers around each implant. Accuracy ranged from -0.06 (95% CI: -0.07, -0.05) to 0.04 (95% CI: 0.01, 0.06) mm, and from -0.38 (95% CI: -0.58, -0.18) to -0.01 (95% CI: -0.08, 0.07) °.

CONCLUSIONS

Model-based RSA is precise and accurate when applied on total wrist arthroplasties, and can therefore be used to measure micromotion in the wrist.

DAY 3

KEYNOTE 4 – Prof Peter Choong

Session Sponsor

Orthopaedics – A technology driven specialty.

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Structural defects and deformities in humans are common. They arise from a variety of common causes includingtrauma, surgery, developmental defects or infection. The specialty of orthopaedics arose from the desire to correct spinal deformities in childhood. With the evolution of the art and science of orthopaedics, the craft now spans the continuum from machines to molecules. The use of biologic, prosthetic and composite materials to afford the correction of defects and alignment has progressed such that complex reconstructions are now commonplace.

Reducing patient morbidity from the use of autologous or allograft tissue has placed the focus on prostheses. Advances in manufacturing and materials have now opened new strategies for reconstructing musculoskeletal defects. Patient specific implants are now the goal of 21st century orthopaedics.

Convergence of synthetic and biologic sciences has resulted in techniques that combine additive manufacturing and stem cell science to allow a new way of customizing implants. These pave the way for exploiting structural design features to improve strength, aid tissue attachment and conform to the part being replaced with the ability to re-engineer specialized tissue from stem cell therapy.

The challenges of future orthopaedics will address the fixation of prostheses, the union of bones, the repair of soft tissue defects and the attachment of tendons. Reestablishing neural continuity and building connections between nerves and synthetic materials will be a dream brought closer to reality through advances in technology. Just in time manufacturing and surgeon-driven sculpting of musculoskeletal tissue will focus the science of biofabrication and cell biology with a greater emphasis on translation.

DAY 3

PARALLEL PODIUM 4 – ANZORS Session

A novel collagen scaffold for improved tendon-bone healing

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INTRODUCTION

Tears of the tendon-bone interface are common, particularly in the rotator cuff, which affects 22% of the general population, and over 50% of those over 60 years old. These injuries show poor healing even after surgical repair. Augmentation with tissue-engineered grafts has been suggested for improved outcomes.

Here, we evaluate a novel collagen scaffold, with an organised lamellar structure and desirable mechanical properties, identified to have potential as a clinically viable tendon tissue augment.

METHODS

The collagen scaffold was fabricated from medical grade bovine type 1 collagen using proprietary techniques. Crosslinking was performed using UV/riboflavin.

In vitro, immune response was assessed by measuring expression of pro-inflammatory cytokines in human monocyte (THP-1) cells cultured with crosslinked and uncrosslinked collagen scaffolds for 24 or 48 hours. alamarBlue® and fluorescent staining were used to determine if the scaffolds could sustain primary tenocyte cell growth over a 7-day period.

In vivo, the supraspinatus was excised from the humerus of 23 sexually mature Sprague-Dawley rats. The tendon was repaired using either sutures alone, or sutures augmented with the uncrosslinked scaffold. Biomechanical properties including elasticity and load to failure, were assessed using an Instron device at 12 weeks post-repair. H&E stained tendon sections were graded for collagen fibre density and orientation, healing at bone-tendon interface, vascularity, and presence of inflammatory cells.

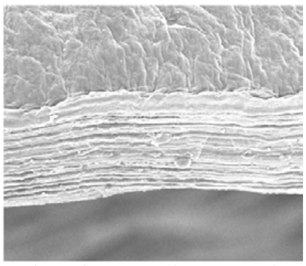

Figure 1: Scanning electron microscopy image of collagen scaffold, demonstrating lamellar structure.

RESULTS AND DISCUSSION

In vitro, results were promising. Neither the crosslinked, nor the uncrosslinked scaffolds increased the expression of pro-inflammatory cytokines (IL-1β, TNF-α, IL-8) in the THP-1 cells compared to either untreated controls or cells exposed to surgical sutures. alamarBlue® and fluorescent staining confirmed adherence and growth of tenocytes on the scaffolds over a seven-day period.

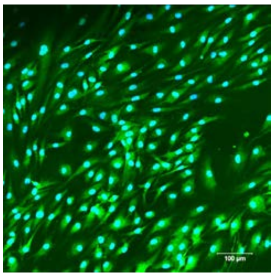

Figure 2: Primary tenocytes cultured on the collagen scaffold for 7 days, captured using confocal microscopy.

In vivo, scaffold augmentation increased elasticity of the repaired tendon-bone interface, but slightly lowered ultimate load to failure. There were no visible structural differences between groups, suggesting the uncrosslinked collagen scaffold did not add any healing benefit during this time period.

CONCLUSIONS

Despite the lack of positive results from the in vivo work, there were no adverse responses to the uncrosslinked collagen scaffold in vivo, while the in vitro results appear promising. Further work is underway to determine whether the crosslinked collagen scaffold may have better in vivo outcomes, by providing more mechanical support to the tendon-bone interface.

Overall, results here suggest that the scaffold is cytocompatible, and the crosslinked scaffold has the potential to augment tendon-bone healing without inducing adverse immune responses.

ACKNOWLEDGEMENTS

This study acknowledges the support of the New Zealand Health Research Council and the Return on Science, NZ investment fund.

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YES

Funding was received from Return on Science, NZ, a national research commercialisation programme that delivers new research to market from universities, research institutions, and private companies.

Co-axial bio-printing of stem cells for the regeneration of articular cartilage

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INTRODUCTION

Articular cartilage injuries experienced at an early age lead to the development of osteoarthritis later in life. 3D printing is an exciting new technology to deliver tissue-engineering techniques in orthopaedics. *In situ* 3D printing has the potential to deliver cutting edge biofabricated scaffolds to regenerate damaged cartilage tissues. The aim of this study was to develop a 3D Bioprinting strategy to create bioscaffolds with high cell viability and good mechanical properties, to finally produce hyaline-like cartilage in vitro.

METHODS

We have created a custom-designed hand-held extrusion ink-jet printing device (Biopen) that allows the simultaneous and co-axial extrusion of biomaterial scaffold (Bioink) and cultured cells, and that can be potentially used directly into the defect that needs to be repaired. The co-axial printing allows the cell laden hydrogel Bioink to be printed as a core, encapsulated by a photocrosslinkable hydrogel as a protective shell for 3D constructs (Fig 1D). Metacrylated Hyaluronic acid hydrogel (HA-GelMa) has ben chosen as Bioink, and Adipose Derived Stem Cells (ADSC) as cell source for cartilage regeneration. *In vitro* tests of survival (Live-Dead stain), and differentiation toward chondrogenic pathway (Histology; IHC for Collagen type I and II, SOX9, Aggrecan; and RT-PCR) have been performed and compared with mono-axial printing (i.e. without using the core-shell structure) at multiple time points. Biomechanical indentation tests have been utilized to evaluate physical properties of regenerated cartilage and compared to mature hyaline cartilage.

RESULTS AND DISCUSSION

ADSC printed in HA-GelMa *in vitro* in a co-axial core/shell distribution remain viable after printing and show marked higher survival when compared to "unstructured" 3D printed cells. The Bioprinted ADSC show a time-dependent increase of expression of SOX 9, Aggrecan and Collagen 2, without the expression of Collagen 1 (Fig 1), markers of hyaline-like cartilage. Finally, the bioprinted ADSC express mechanical properties over time indicating cartilage matrix production by chondrocytes.

We have identified a 3D printing condition, the co-axial core/shell distribution, that allows increased cell survival when compared to mono-axial printing, and simultaneously achieves better biomechanical properties. These characteristics make the co-axial printing an ideal solution for bioprinting of biological tissues.

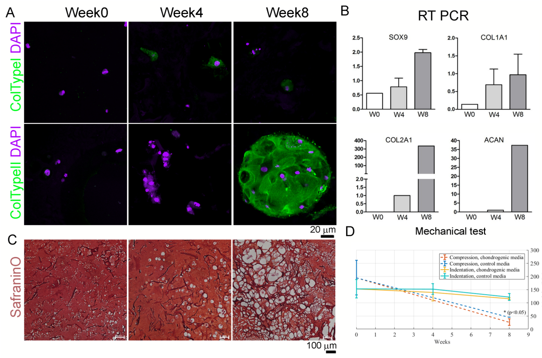

Figure 1: Representative confocal images of 10 mm cryosections stained with anti-Collagen Type 1/2 and counterstained with Hoechst. **(B)** Gene expression levels expressed as Fold Increase measured with Quantitative RealTimePCR and normalized versus Week4 time point. **(C)** Representative brightfield images of 10 mm cryosectioned samples stained with SafraninO. **(D)** Young modulus (KPa) relative to compression and indentation measurements.

CONCLUSIONS

The Biopen, as a hand-held 3D Bioprinter, allows the applicability of this innovative strategy directly to the surgical field. We have also demonstrated that the cells embedded in the HA-GelMa Bioink, in chondrogenic conditions have the ability to differentiate towards articular cartilage.

ACKNOWLEDGEMENTS

This study has been partially funded by Arthritis Australia – Zimmer Australia grant, and by the Research Endowment Funds – St Vincent's Hospital, Melbourne.

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Human Spinal Bone Dust as a Potential Local Autograft: In vitro Potent Anabolic Effect on Human Osteoblasts

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INTRODUCTION

Surgical fusion is the standard of care in the management of a number of spinal disorders, ranging from traumatic vertebral injuries to degenerative spinal disease [1]. Despite this, failure to achieve a solid bony fusion occurs in <40% of patients undergoing spinal fusion surgeries.

Clinically, a number of bone grafting options can be used to optimize fusion, with the 'gold standard' being autologous iliac crest bone [2]. However, significant limitations exist with its use, including limited harvest and donor site morbidity.

Bone dust, created by burrs during the posterior surgical approach to the spine is a free source of autologous bone that is usually lost through suction. By using a simple suction trap, bone dust can be collected at no additional risk to the patient.

Macroscopically, bone dust resembles a pate, which is malleable and can be grafted back to the surgical site (Figure 1A). Microscopically, bone dust is composed of bone (65%), mixed with blood products and fibrous tissue.

A number of studies have demonstrated that bone dust is a source viable osteoblasts and stem cells with osteogenic potential [3-4]. From a regenerative point of view, the cellular components and blood products that make up bone dust could also be a source of anabolic factors which could be released into the host environment and promote bone formation.

The objective of this study, therefore, was to quantify the growth factors and cytokines released from human bone dust and evaluate the effect of these factors on primary human osteoblast growth and maturation.

METHODS

Bone dust was collected from consenting patients undergoing elective posterior spinal fusion surgeries, and primary human osteoblasts were cultured from patients undergoing elective hip or knee arthroplasty for osteoarthritis.

Growth factors and cytokines released by bone dust into media were quantified using enzyme-linked immunosorbent assay (ELISA) over a 7-day period.

For cell assays, bone dust was transferred to tissue culture inserts with 1μm pore size. The tissue inserts containing the bone dust was suspended over primary human osteoblasts cultured in 24-well tissue culture plates (Figure 1B). Primary human osteoblast proliferation and gene expression in response to the anabolic factors released by bone dust were assessed using 3H-thymidine incorporation and real-time polymerase chain reaction (qPCR), respectively.

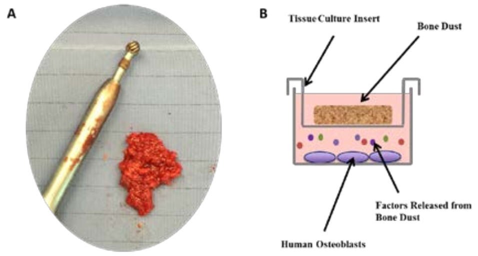

Figure 1: **A** - Bone dust created by burr. **B** – Culture design with tissue culture inserts.

RESULTS AND DISCUSSION

Human posterior spinal bone dust released a number of anabolic growth factors (TGF-β, PDGF-BB, VEGF) and cytokines (IL-1β and IL6) in increasing concentrations over a 7-day period. In vitro, the anabolic factors released by bone dust led to a 7-fold increase in primary human osteoblast proliferation compared with osteoblasts cultured in standard tissue culture media. In addition, the anabolic factors released from bone dust triggered an up-regulation of a number of osteoblastic genes integral to osteoblast differentiation, maturation and tissue angiogenesis.

CONCLUSIONS

This study is the first to demonstrate that human posterior spinal bone dust is capable of releasing anabolic factors that potently enhance human osteoblast proliferation and the expression of genes that favour bone healing and regeneration. Thus, bone dust has therapeutic potential as an autologous graft material in spinal fusion surgeries. Give that bone dust harvest is fast, simple, cheap and safe to perform, spinal surgeons should be encouraged to 'recycle' spinal bone dust and harness the regenerative potential of this free autologous bone graft.

ACKNOWLEDGEMENTS

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COMBINATION LOADING PRODUCES A CHONDROGENIC PHENOTYPE THAN UNIAXIAL LOADING

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INTRODUCTION

The knee joint is one of the most complex organs in our bodies, and is one the most susceptible to injury. Traumatic injuries to the knee joint can cause pain and instability, altering joint loading patterns, which in turn can cause a cascade of events that leads to the development of osteoarthritis. Investigations to understand the onset and development of this disease are often carried out by applying simple loads using mechanical devices on chondrocytes seeded in 3D hydrogel culture models.

However, these loads do not simulate the full complexity of physiological knee loading. In order to better understand how changes in mechanical loading affects chondrocytes, we developed the first, precise multiaxial-loading device that can apply a simultaneous combination of compression, shear, and tensile cyclic loading on an *in vitro* hydrogel model. Chondrocyte responses were measured following loading regimes that represented physiological joint loading and over-use injurious loading.

METHODS

The multiaxial-loading device was developed, and the accuracy of loading was validated. Custom 3D agarose-chondrocyte rectangular constructs (15 x 13 x 3 mm) were designed and optimised to withstand mechanical loading. Murine articular chondrocytes were seeded in 3% w/v agarose, and casted in sterile moulds containing mesh ends that would attach to the device. Constructs were cultured for 14 days, with several techniques used to validate this system; (i) cell viability and phenotype were validated by live-dead and extracellular matrix staining; (ii) device was validated by measuring the strain within the construct during applied loading, and measurements of cellular shape (Figure 1).

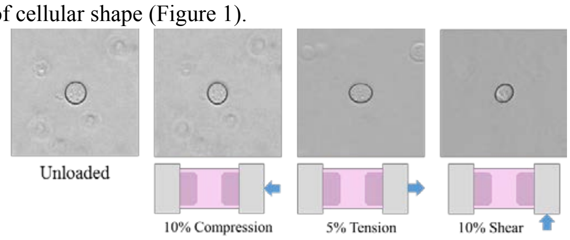

Figure 1: An example of cellular shape change under the different singular loading modes.

At the end of the culture period, sets of constructs were subjected to two cyclic mechanical loading regimes: physiological (intermittent 2 hours loading for 16 hours with 8 hour rest period), and injurious over-use (continuous loading for 24 hours). Four loading modes were used for each loading regime; 10% compression, 5% tension, 10% shear, and a combination of the three. Real-time PCR was used to determine changes in the expression of genes for each of the loading modes under each of the loading regimes. Eight genes were chosen that were important in cartilage matrix remodelling; collagen type 1 and 2, aggrecan, cartilage oligometric matrix protein, matrix metalloprotease-3 and -13, ADAMTS-5, and TIMP-1.

RESULTS AND DISCUSSION

The chondrocyte model maintained above 90% viability over the culture period, and showed extracellular matrix production. Strain through the construct were relatively uniform and close to applied strain.

Combination loading did not significantly increase anabolic response in chondrocytes. It did, however, produce a more balanced production of collagen types 2 and 1 compared to the other modes of loading. Continuous combination strain loading, meanwhile, produced an increased expression of collagen type 2 in the cells, representing a more stable chondrogenic phenotype compared to single loading modes.

Despite high expression of genes in compression or shear loading, combination loading produced lower levels of gene expression, following the trend in tensile loading. This suggests that tensile loads modulates the metabolic responses of chondrocytes and should be considered further in loading regime designs.

Overall, the combined cyclic loading lead to no significant change in the majority of cartilage matrix gene expression, but produced a more chondrogenic phenotype compared to other single modes of loading. Although we are unsure why this is, one hypothesis is that when strains are combined, the loading modes simulate a more physiologically relevant loading, promoting homeostasis, closely mimicking complex loading of normal *in vivo* cartilage.

CONCLUSIONS

The system developed in this research is the device best capable of fully mimicking *in vivo* conditions in health and disease. Work here has significantly enhanced our knowledge of chondrocyte mechanobiology that will enable a better understanding of injury induced osteoarthritis.

ACKNOWLEDGEMENTS

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The influence of Si-doped titania nanotube arrays on endothelial cell functionality

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INTRODUCTION

Rapid promotion of ECs functionality over the stent surface is crucial to the success of coronary stents [1]. The accumulated evidence shows that both surface chemistry composition of the implanted bio-medical device and surface topography at the nanoscale are critical parameters for cellular recognition of the implanted stents. Recent research shows that titania nanotube arrays (TNAs) could provide a hemocompatible surface and enhance ECs proliferation [2]. More importantly, studies also demonstrate that TNAs could significantly enhance the secretion of VEGF, while they regulate downstream signaling and expression of related genes involved in the critical steps of the ECs functionality.

In addition, due to their one-end opening geometry, TNAs can be considered as an ideal carrier to load bioactive elements, such as copper (Cu) and silver (Ag), generating new specific functions. With this in mind, this paper introduces the Si element into the TNAs and focuses on the effect of the Si on ECs. This study would provide a new insight for their potential use to address issues associated with ISR for improved coronary stenting application.

METHODS

Ti foils introduced into the deposition chamber. Pulsed direct current (DC) magnetron sputtering was carried out to deposit the TiSi coatings on the substrates using four Ti-Si targets with different Si contents. Anodization was carried out in a conventional two electrodes configuration with the as-deposited Ti-Si coatings as the working anode and a graphite rod as the counter electrode. LDH leakage was determined using a commercial LDH Kit (Nanjing Jiancheng Biological Product, China) according to the manufacturer's instructions. The VEGF ELISA kit (Quantikine human VEGF Immunoassay kit, R&D Systems, Minneapolis, MN) was carried out to determine the amount of VEGF secreted by ECs.

RESULTS AND DISCUSSION

The results of this in vitro investigation indicate that TNA-Sis could significantly enhance ECs functionality without altering their native functions in comparison to TNAs. ECs viability is found to be improved on all TNA-Sis with respect to TNAs. TNA-Sis are also found to promote functional properties such as VEGF production by ECs. These data demonstrate that the combination of TNAs and the biological elements of Si provide an ideal strategy to promote the recovery of endothelium on the surface of the coronary stents, and might address the long-term complications of the in-stent restenosis and subsequent thrombosis.

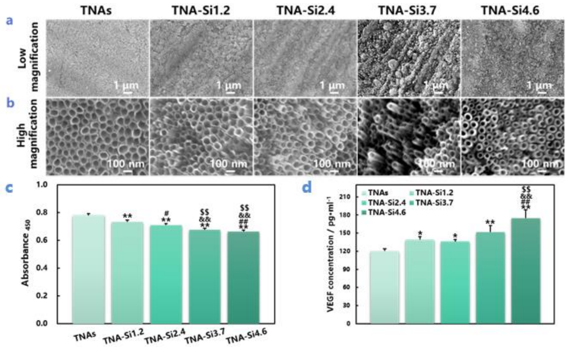

Figure 1: SEM images of TNAs and TNA-Sis with different Si contents: 1.2 at%, 2.4 at%, 3.7 at% and 4.6 at%. There are two levels of magnification (a) and (b) of the nanotubes; (c) Cytotoxicity assay by evaluating LDH activity in the culture media after 24h culture of endothelial cells on TNAs and TNA-Sis; (d) VEGF concentrations secreted by endothelial cells after culturing for 1 day.

CONCLUSIONS

In this work, we have fabricated the TNA-Sis with different Si contents via anodization of the magnetron-sputtered TiSi coatings. The results of this in vitro investigation indicate that TNA-Sis could significantly enhance ECs functionality without altering their native functions in comparison to TNAs.

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DESIGN OF A NOVEL JOINT REPLACEMENT FOR THE HUMAN TEMPOROMANDIBULAR JOINT

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INTRODUCTION

End-stage disorders of the temporomandibular joint (TMJ), including osteoarthritis and condylar resorption, have a prevalence ranging from 16-59% [1]. TMJ replacement surgery is the established treatment for advanced TMJ osteoarthritis; however, current TMJ prosthetic implant designs face a range of problems including fracture from metal fatigue; screw loosening; and mandibular nerve damage. Three-dimensional (3D)-printing has transformed capacity to quickly design and manufacture implantable components at low cost; however, tools for evaluating pre-operative implant functional performance are currently limited. One of the most critical factors in implant load response and longevity is prosthesis geometry, since implant shape is known to contribute significantly to joint loading and, therefore, to failure by wear and loosening. The aim of this study was to design a personalized joint replacement for the treatment of Grade-5 osteoarthritis in a patient's right TMJ, and to evaluate the influence of changes in prosthesis design parameters on predictions of implant loading, including prosthesis thickness, neck length, and condylar head sphericity.

METHODS

A female patient (age: 48 yrs, weight: 63 kg) with symptomatic and radiographic osteoarthritis of the left TMJ was recruited. Computed Tomography (CT) images of the patient's skull and jaw were obtained and digitally segmented to reconstruct 3D surfaces of the skull, mandible and glenoid fossa. A finite element model of the patient's jaw was then developed from this geometry, with the major muscles of mastication – the masseter, temporalis (anterior and posterior), lateral and medial pterygoids – represented as ideal muscle actuators. A scaled-generic rigid-body musculoskeletal model of the patient's jaw and masticatory system was then developed in OpenSim, and used to calculate muscle forces during mastication, with a peak bite-force of 200N [2]. The calculated muscle forces were then used as boundary conditions in the finite element model.

A personalised prosthetic TMJ system was designed for the patient and implanted into the finite element jaw model via virtual surgery. Simulations of mastication were then performed, and repeated by varying by ±30% the prosthesis thickness, condylar neck length, condylar head sphericity and condylar head lateral offset. Peak TMJ contact forces, as well as mandibular bone, screw and prosthesis stresses were subsequently reported.

RESULTS AND DISCUSSION

The peak prosthetic TMJ force magnitude calculated during chewing was 55.5 N, which decreased to 47.6N with a 30% shorter neck, but increased to 100.5 N with a 30% less spherical condylar head. Reducing the thickness of the prosthesis by 30% increased the peak condylar stress from 105 N to 172 N, and increased the peak screw stress from 167 N to 207 N. Increasing the prosthesis thickness by 30% had little effect on the peak condylar stresses or screw stresses. The underlying mandibular bone stresses were invariant to any perturbations in implant geometry. Lateral offset of the condylar head had a negligible influence on the calculated joint forces or prosthesis stresses.

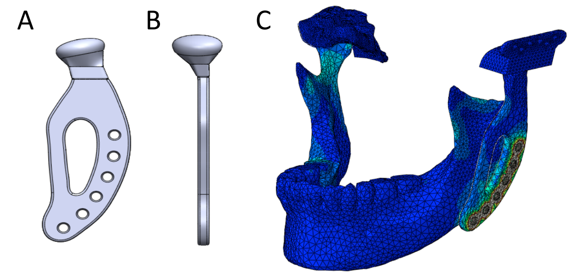

Figure 1: Front profile of condylar component of prosthetic TMJ replacement (A), side profile of condylar component (B), and nominal stress distribution during mastication (C).

CONCLUSIONS

This study describes the development and testing of a personalised TMJ for a patient with end-stage osteoarthritis of the jaw. The results showed that prosthesis thickness has the most significant influence on screw and implant stresses, as well as condylar head sphericity. A flat condylar head is typically employed in prosthetic TMJ designs to facilitate joint translation, however, excessive flatness of the condylar head can greatly increase joint force, and present increased risk of early prosthetic condyle loosening. The results of this study may be useful for modelling, development and manufacture of improved personalised joint replacements for the treatment of osteoarthritis, trauma, congenital abnormalities and tumour resection associated with the TMJ.

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VALIDATION OF FULL BODY OPENSIM MODEL WITH DETAILED LUMBAR SPINE TO EVALUATE BIOMECHANICS OF LIFTING TASKS

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INTRODUCTION

Low back pain (LBP) is a widespread problem in western countries [1] and although considered idiopathic, lifting is an independent risk factor [2]. Several models of the spine have been developed to estimate intervertebral joint and spinal muscle forces from kinematic and kinetic data, including two using the modelling software OpenSim [3,4]. However, few OpenSim full-body models have been developed [5,6] and to the authors' knowledge, none of the publicly available models have been validated specifically for lifting tasks. The aim of this study was to validate muscle activation and intervertebral loads estimated by a full body OpenSim model with a detailed lumbar spine, specifically for lifting tasks. The results for a single subject are presented in this abstract.

METHODS

The OpenSim model used in this study is a modified version of a full-body model [5] that includes a detailed lumbar spine [3]. Kinematic and kinetic data of three lifting tasks with a load of 5 kg (two-handed squat (SQ), two-handed stoop (2ST), and one-handed stoop (1ST) were collected for one male participant (30 yrs, 81.9 kg), with a 12-camera Vicon motion analysis system (Oxford Metric, UK) and two force platforms (AMTI, USA), with sampling rates of 100 Hz and 2000 Hz, respectively. EMG was recorded at a sampling rate of 2000 Hz using 10 surface electrodes (Delsys, USA) placed bilaterally over the abdominal and back muscles [7].

The model outputs were verified using two approaches: 1) comparison between the muscle activation patterns estimated by the OpenSim model and the corresponding measured surface EMG signals; 2) comparison between spinal loads estimated by the model and those recorded by telemeterised vertebral body implants during lifting tasks [8].

RESULTS AND DISCUSSION

The back muscle activations predicted by the model closely matched the activation patterns measured by EMG (Figure 1) for the lifting techniques evaluated. The L1 maximum vertebral compression loads estimated by the model (592% and 600% of standing load, for SQ and 2ST, respectively) were comparable to the average L1 maximum vertebral compression loads recorded by telemeterised implants for three subjects lifting a 7 kg load (465% and 507% of standing load, for SQ and 2ST, respectively).

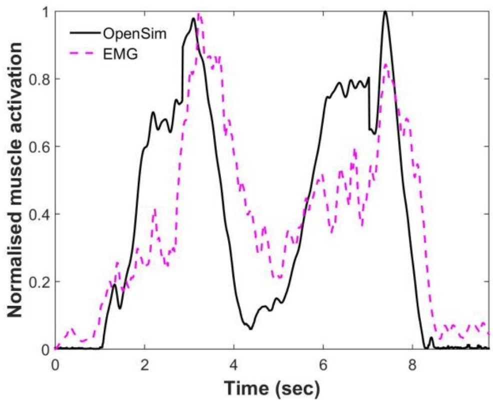

Figure 1: Measured EMG and muscle activation estimated by the model for the right lumbar erector spinae during a squat.

CONCLUSIONS

The preliminary validation results indicated that the full body OpenSim model evaluated in this study estimated spinal muscle activations similar to the measured EMG and spinal loads of reasonable magnitudes for the lifting tasks undertaken.

ACKNOWLEDGEMENTS

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HOW THE THERAPEUTIC GOODS ADMINISTRATION (TGA) USES ORTHOPAEDIC IMPLANT REGISTRY DATA

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ABSTRACT

The Australian Orthopaedic Association (AOA) National Joint Replacement Registry (NJRR) has been operating since 1999, and publishes an annual report alongside several supplementary reports every October. The 2016 Annual Report…

> "...includes detailed information on all primary and revision hip, knee, and shoulder procedures undertaken up to the end of 2015. This includes 498,660 hip, 592,577 knee and 32,406 shoulder procedures" [1]

The annual reports contain information about the types and reasons for revision procedures and identify implant combinations that have a higher than anticipated rate of revision and Registry information is also available through a web portal. Thus the information is a rich resource for orthopaedic surgeons, manufacturers, researchers and regulatory agencies.

An implant may be having a higher than expected rate of revision for many reasons, and these must be considered before contemplating regulatory action. In 2006 the TGA established a unique process for the investigation of "identified" implants.

Of the 77 implants that are "identified and no longer used", 32 were withdrawn from the market after TGA intervention, and the TGA has also intervened in many other instances.

The outcomes of such interventions are published on the TGA website (www.tga.gov.au), and the AOA and surgeons that used the implants subject regulatory outcomes are notifed individually.

The TGA also uses registry information to check the revision rate of implants subject of a Device Incident Report, and has also used registry information in the assessment of products that are new to the market, both to the benefit and the detriment of applications for pre-market approval of the implants.

CONCLUSION

TGA's use of registry information has led to many significant regulatory outcomes.

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DAY 3

PARALLEL PODIUM 4 – RSA Session

UNEXPECTED MIGRATION BETWEEN THE HEAD AND STEM IN MODULAR NECK HIP IMPLANTS

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INTRODUCTION

The use of a modular femoral neck on a stemmed hip implant allows optimization of neck anteversion, leg length, and offset, resulting in an improved biomechanical situation. A problem that has been revealed is that corrosion and fretting of the neck-stem junction can lead to an increased release of metal ions that can result in adverse local tissue reactions and maybe mechanical failure [1]. In July 2012, Stryker decided to voluntarily withdraw the ABG II modular neck hip system from the marked for these reasons.

In 2010, we started an RSA randomized controlled trial (RCT) to compare migration of the ABG II modular neck hip system with the standard non-modular neck ABG II system and to measure the ability to restore the individual anatomy with the different neck options. The ABG II hip prosthesis has a titanium alloy (TMZF) stem and a CoCr head. The modular neck is also made of the same CoCr alloy. All patients in the study have later also been measured regarding metal ion levels in blood and MRI have been performed to measure adverse tissue reactions. During RSA analysis for that study, it was noted at the 5-year follow-up that the femoral stem head seemed to be migrating with respect to the femoral stem body. We decided to further investigate this phenomenon and therefore the goal of the current study was to evaluate the movement of the stem head in relation to the stem tip to see if there is a difference between stems with modular necks and standard non-modular necks. Further, we wanted to study the relation between this movement and other parameters such as neck angle, neck length and patient body weight.

METHODS

In this study, 49 modular and 25 non-modular stems of the same basic design (ABG-II, Stryker) were analyzed. RSA examinations where made directly post-op and at 0.5, 3, 12, 24, and 60 months. Model-based RSA analysis was done using the EGS-hip analysis method that includes accurate estimation of the positions of the head and distal tip of the hip [2]. Changes in head-tip distance were measured using post-op as a reference. For the modular group, the changes in head-tip distance were also related to femoral neck length and angle and to patient body weight.

RESULTS AND DISCUSSION

The head-tip distance reduced significantly over time for the modular neck stem (Table 1). At 60 months, the mean change was -0.72 mm (range: -1.53; 0.14mm). For the non-modular neck stem, the change was much less: Mean change at 60 months was -0.07 mm, (range: -0.77; 0.32mm).

A linear mixed model fit of head-tip distance change using the patient as random effect and group/time (modular versus non-modular) as fixed effects revealed that for the modular group, the head-tip distance changed by -0.14 mm/year (confidence interval: -0.15; -0.13), while for the non-modular group this was -0.01 mm/year (confidence interval: -0.03; -0.00).

The 49 modular hips were studied in further detail to reveal the influence of neck length (short/long), neck angle (125^0/130^0/135^0) and patient body weight. A linear mixed model fit of head-tip distance reduction using the patient as random effect and angle/time, size/time, and weight/time as fixed effects showed that the head-tip distance reduction is larger for long neck lengths and 125^0 neck angles. Patient body weight had no significant effect.

CONCLUSIONS

This study indicates that corrosion and fretting problems of the modular neck of the ABG II modular neck stem results in movement of the stem head with respect to the stem tip. It also shows that this motion is larger for longer necks with a neck angle of 125^0, which is probably due to larger moment forces. We believe this micromotion occurs in the affected neck-stem junction with compression and varus tilt of the neck in relation to the stem body. For the non-modular neck stem, the head movement in relation to the stem tip is negligible. This is a new phenomenon describing movement within the actual hip stem and we do not know if it has any long-term negative effects or indicates a risk of later mechanical failure. The findings emphasize, however, the importance of phased introduction of new implants and designs, including an RSA RCT before widespread introduction on the market.

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Table 1: Mean and Standard Deviation of the Reduction in Head-Tip Distance in mm for different Follow-Up moments in Months.

Follow-Up (months)		0.5	3	12	24	60
Modular Hip	N = 49	-0.06 (0.15)	-0.11 (0.16)	-0.17 (0.17)	-0.28 (0.18)	-0.72 (0.39)
Non-Modular Hip	N = 25	-0.00 (0.11)	-0.02 (0.15)	-0.04 (0.14)	-0.05 (0.13)	-0.07 (0.20)

CONFLICT OF INTEREST DECLARATION

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

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   Stryker has unconditionally sponsored part of the RSA-analysis

THE WEAR RATE OF HIGHLY CROSS-LINKED POLYETHYLENE IS NOT INCREASED BY LARGE ARTICULATIONS: MID TERM FOLLOW-UP OF A RANDOMISED CONTROLLED TRIAL

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INTRODUCTION

Larger articulations reduce the risk of dislocation following primary total hip replacement (THR) [1], leading to increased use of these articulations. The wear rate of highly cross-linked polyethylene (XLPE) is low in standard-diameter articulations but remains unclear in larger articulations at mid- to long term follow-up. Wear rates of larger articulations against XLPE liners have varied between 0.00 and 0.06mm/year [2]. One of the main factors influencing these reports is the measurement method used. Radiostereometric analysis (RSA) is recognised as the gold standard for in vivo wear measurement [3]. We have previously reported that the linear wear rate was not increased using a large 36mm metal-on-XLPE articulation compared to standard 28mm articulation at three years post primary THR.

The aim of this study was to compare the mean wear rates of 36-mm and 28-mm metal-on-XLPE articulations at mid-term follow-up.

METHODS

Fifty-six patients undergoing primary THR at the Royal Adelaide Hospital were randomised intraoperatively to receive either a 36- or 28-mm metal-on-XLPE articulation. All patients received the same cemented femoral stem with either a 28- or 36-mm cobalt chrome head (CPT, Zimmer, Warsaw IN), an uncemented acetabular component (Trilogy, Zimmer), and the same XLPE liner (Longevity, Zimmer). All patients were aged between 65 and 74 years at the time of surgery. Factors that may affect wear were controlled by study design. The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12613000860763).

Femoral head penetration was measured using RSA examinations taken at 4 days, 3 months, 1, 2, 3, 5, 7 and 10 years post THR. To allow for bedding-in, the wear rate was calculated for each individual using the slope of FHP results at 1 year and thereafter. RSA measurements were undertaken using UmRSA software (v6.0, RSABiomedical, Umea Sweden).

RESULTS AND DISCUSSION

Median annual proximal wear rates between 1 and 7 years were below 0.01 mm/yr for both the 36 and 28-mm articulation cohorts, respectively. No patient had a proximal wear rate of >0.1 mm/yr. Mean wear was very low in all directions, and the proximal, medial, 2D, and 3D wear rate of 36-mm articulations was not significantly greater than that of 28-mm articulations.

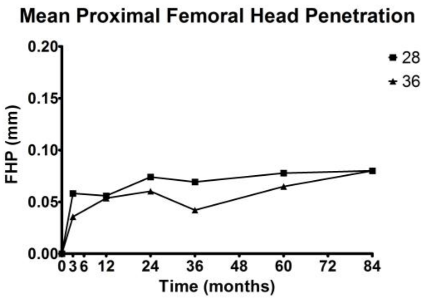

Figure 1: The mean femoral head penetration over time for both 28- and 36- articulations.

CONCLUSIONS

The wear rate of a larger 36-mm metal-on-XLPE articulation between 1 and 7 years following primary total hip arthroplasty was low and no greater than that of a 28-mm articulation. However, before a 36-mm metal-on-XLPE articulation is widely recommended, particularly in young active patients, the long-term association between wear and periprosthetic osteolysis is yet to be determined.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge co-operation of patients, surgeons and staff at all centres involved in this study.

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CLINCAL WEAR RESULTS FOR A VITAMIN-E STABILIZED POLYETHYLENE ACTEABULAR LINER USING A NOVEL MODEL-BASED APPROACH FOR MEASURING WEAR IN RADIO-OPAQUE CUPS

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INTRODUCTION

Wear particle induced osteolysis is a major cause of aseptic loosening in hip arthroplasty [1]. To reduce the incidence of wear particles, warm-irradiated, Vitamin E blended highly cross-linked polyethylene liners (XLPE) were designed to improve oxidative stability, strength and wear resistance.

The clinical wear of a warm-irradiated, Vitamin-E blended XLPE was assessed using a novel method to measure wear for cases where femoral head visibility is reduced by radio-opaque cups.

METHODS

Imaging data from patients enrolled in an ongoing prospective clinical study entitled "A Prospective Radiostereometric Analysis and Clinical Evaluation of the Zimmer® Continuum® Acetabular Cup with Vitamin E Stabilized Polyethylene" (Zimmer Biomet, Warsaw, IN) were reviewed as part of the study protocol. Fifty-five patients undergoing primary total hip arthroplasty with the Principal Investigator (SS) at Northwestern Medicine Central DuPage Hospital provided consent to participate in the study. Study patients received the Zimmer Continuum Cup with Vivacit-E® polyethylene liner and the BIOLOX® *delta* ceramic head. Femoral head diameters ranged from 32mm to 40mm. Standing RSA exams were used to measure liner wear and were taken at the 6, 12 and 24-month post-operative follow-up time points. Fifty-one patients have reached their 24-month follow-up at the time of this analysis.

Partial visibility of the femoral head in stereo radiographs prevented traditional model-based wear calculations. To identify the center of the femoral head, custom femoral stem/ head models were created for each patient. To accommodate for patient differences in femoral head position due to the nature of press-fit components, a novel 7-degree of freedom optimization algorithm was created and processed in MatLab (The Matworks, Natick, NA). The algorithm treats the femoral head and stem as a kinematic pair, linked with prismatic coupling. Using the 6-month standing exams to determine the individual position of the head on the femoral stem, combined custom models were created for each patient, and the model-fits were performed with Model-based RSA version 3.4 software (RSA*core* Leiden University Medical Center, Leiden, The Netherlands). Wear was then calculated in MatLab using point motion analysis.

Fourteen patients missed a standing exam or at least one follow-up and 2 patients withdrew from the study resulting in thirty-five patients being included in the clinical wear analysis.

The precision of the technique was calculated as the standard deviation of wear measured between 53 double post-operative examinations.

RESULTS AND DISCUSSION

Precision of the wear measurements was 0.061mm, 0.046mm and 0.112 mm in the medial, proximal and anterior directions, respectively. Anterior precision is measured in the out of plane axis, where lower precision is expected. Proximal femoral head penetration between the 6-month and 24-month standing exams was 0.002 ± 0.087mm. The two dimensional wear for all patients is depicted graphically in Figure 1. The mean (SD) annual proximal wear rate between 12 and 24 months was 0.003 ± 0.077mm.

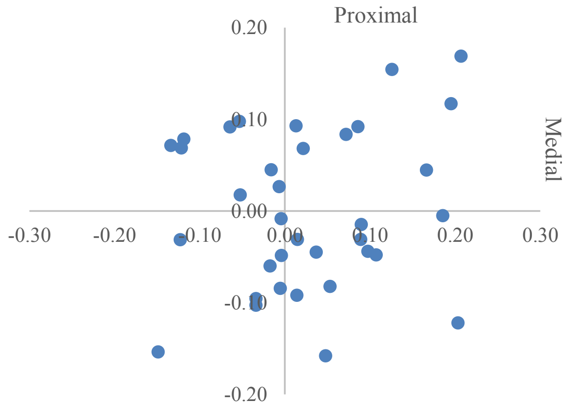

Figure 1: Femoral head penetration into the Vivacit-E acetabular liner between 6 and 24 months post-operation.

CONCLUSIONS

Wear of the Vivacit-E polyethylene liner was low over the first two post-operative years, and measureable with our novel approach.

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CONFLICT OF INTEREST DECLARATION

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

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1. The author(s) did receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity.
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   The above study was funded by Zimmer Biomet. The Principle Investigator, Scott Sporer, is a paid consultant of Zimmer Biomet.

2. A commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

   Zimmer Biomet approved this study and provided funding to the institution (Central DuPage Hospital), but was not involved in data collection, analysis or interpretation.

SIMILAR PRESS-FIT FIXATION WITH A SPHERICAL AND A CONICAL CUP DESIGN IN THE TRAPEZIOMETACARPAL JOINT: A RADIOSTEREOMETRIC ANALYSIS IN A PIG MODEL

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INTRODUCTION

Trapeziometacarpal total joint arthroplasty (TMTJ) is a recognized treatment for painful osteoarthritis in the trapeziometacarpal joint, which result in better grip strength and faster rehabilitation compared with trapeziectomy. However, high and early loosening rates of the cup is a problem [1], and therefore newer cementless cup designs have been introduced. The "Type T" TMTJ (Beznoska) is a spherical titanium (Ti) and hydroxyapatite (HA) coated cup with 3 rim-spikes, where the surface of the remaining cartilage and sclerotic bone is removed with an alignment cutter prior to reaming and press-fit cup insertion. The "Moovis" (Stryker) is a conical Ti and HA coated cup intended for cortical bone fixation, and none of the trapezium cartilage surface is removed prior to reaming and press-fit cup insertion. The purpose of this study was to compare the primary cup fixation of these two cup designs during a load stress-test in a pig bone model by use of radiostereometric analysis (RSA) [2,3]. We hypothesized more subsidence and quicker failure of the Type T spherical cup compared with the Moovis conical cup.

METHODS

20 pig feet were DXA scanned and the bone mineral density of the "trapezium equivalent bones" were measured [3, 4]. Thereafter 10 conical Moovis cups and 10 spherical Type T Besnoska cups were inserted into the bones using the recommended surgical technique and original instrumentation [2]. Five tantalum beads 1-mm were inserted in the periprosthetic bone whereafter the bones were fixed in Palacos bone cement with the surface at an approximate 20 degree angle with the horizontal plane to recreate the clinical loading angle in the TMC joint. Static RSA was performed at baseline, after a low-pressure cyclic push-in loading test (300 cycles at 150N), and then sequentially at every 150N step increase during a maximal load push-in stress test (2 cycles with 50N increase until visual implant failure). Cup subsidence was evaluated in the length axis of the cup. We performed double RSA examinations for assessment of precision.

RESULTS AND DISCUSSION

RSA precision was 0.06mm (we rounded up to 0.1mm) for subsidence in terms of 95% agreement limit. The T type cup and the Moovis cup migrated significantly within groups only after the 750N load ($p<0.04$; ANOVA Tukey post hoc test). There was no difference in subsidence between groups at any load test ($p>0.05$; unpaired two-sample ttest) (Figure 1).

At 600N load 9 out of 10 Type T cups and 3 out of 9 Moovis cups migrated above the 0.1mm precision limit ($p=0.18$; Fischer exact test). The load for visual clinical failure coincided with a measured subsidence of approximately 1mm. In total, 7 out of 10 Type T cups and 4 out of 10 Moovis cups failed ($p=0.18$; Fischer exact test). The failure pattern for the Type T cup was subsidence of 1mm or more associated with a cup tilt between 8° and 18°. The failure pattern for the Moovis cup was merely subsidence.

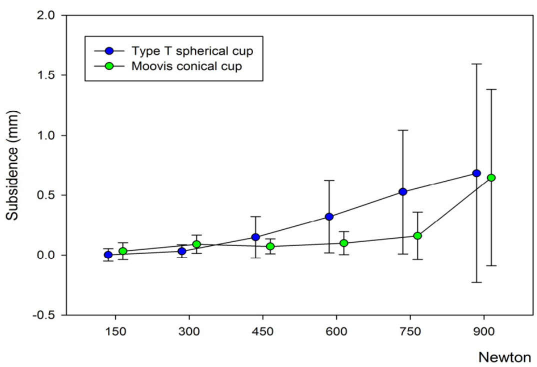

Figure 1: Mean (SD) subsidence of the two trapezium cups at progressive cyclic loading.

CONCLUSIONS

Both cup designs were well fixed until 750N cyclic loading. A 750N load on the cup resembles a thumb-to-index pinch of 6.3kg, which is a clinically relevant maximum pinch. This underlines the importance of unloading the TMC joint in the clinical setting until after osseointegration in the cup surface. There was no statistically significant difference in fixation for the two cup designs, but the migration pattern indicated progressive subsidence and tilt for the spherical cup and a more sudden and direct subsidence for the conical cup. We suspect that especially the quality of cortical bone fixation is important for the cup fixation strength and migration pattern.

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4. Hansen TB, et al. *J Hand Surg Eur.* **38(8)**:875-9, 2013.

GOOD 2 YEAR RESULTS WITH A NEW CONICAL PRESS-FIT CUP DESIGN AND DUAL-MOBILITY ARTICULATION IN TOTAL TRAPEZIOMETACARPAL ARTHROPLASTY

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INTRODUCTION

Trapeziometacarpal total joint arthroplasty is a recognized treatment for painful osteoarthritis in the trapeziometacarpal joint (TMJ), which result in better grip strength and faster rehabilitation compared with trapeziectomy. However, cup failure and dislocation is a recognized problem leading to a high revision rate between 20-40% dependent on cup design and fixation method. This has sparked an ongoing interest in introduction of new cup designs for TMJ arthroplasty. The "Moovis" Elektra (Stryker) cup is a conical Ti and HA coated implant intended for cortical bone fixation. The articulation is a dual-mobility UHMWPE on a 5mm CoCr metacarpal head. Radiostereometric analysis has formerly been used to evaluate cup fixation in TMJ arthroplasty [1-3]. The purpose of this study was to evaluate cup fixation and polyethylene (PE) wear of the Moovis cup as a phased introduction [4] in our clinic.

METHODS

A case-study of the first 111 consecutive patients (111 hands, 89 females) with Eaton stage 2-4 osteoarthritis of the TM joint scheduled for surgery with the 9mm Moovis Elektra press-fit dual-mobility TMTJ arthroplasty (June 2013 thru May 2015). Required ethics approval and database registration was obtained. Bone Mineral Density (BMD) was measured pre-operative in the trapezium. Five tantalum beads 1-mm were inserted in the periprosthetic bone. Static stereoradiographs were obtained in a standard RSA setup (AdoraRSA, NRT, Denmark) with a small uniplanar perspex box (Medis Specials, The Netherlands). Cup migration was evaluated with model-based RSA (RSAcore, The Netherlands. Total Translation (TT) for cup migration was calculated with Pythagoras Theorem (square root $x^2+y^2+z^2$). Cup subsidence was evaluated in the length axis of the cup. Polyethylene wear was measured with model-based RSA using cup feature points. Double RSA examinations were obtained for assessment of precision. Stereoradiographs, DASH score, VAS pain, and hand function were evaluated at baseline, 3 months, 1 and 2 years.

RESULTS AND DISCUSSION

Patients were mean 58 years (range 42-76). Preoperative the trapezium BMD was 0.68 g/cm^2 (range 0.47-1.04). Precision was 0.15 mm 95% limits of agreement. TT cup migration at 2 years followup was mean 0.46 (SD 0.48) mm, and there was an increase in TT from 3 months to 2 years (p=0.01). Preoperative, trapezium BMD was mean 0.68 g/cm^2 (range 0.47-1.04). TT cup migration at 2 years followup was mean 0.46 (SD 0.48) mm, and there was an increase in TT from 3 months to 2 years (p=0.01). Cupsubsidence was 0.02 mm (SD 0.35) at 2 years followup, indicating good cortical bone fixation. At 2 years 13 cups (15%) had migrated more than 1mm in TT, while 80 cups had less than 1mm migration (p=0.00), but no cups were revised at 2 years followup and VAS pain, VAS activity and DASH was similar between groups (p>0.17). There was no correlation between pre-operative BMD and cup subsidence or TT cup migration (p>0.48). DASH score improved mean 29 (SD 21) and grip strength improved 5.3 kg (SD 10.0) from preoperative to 1 year (p=0.000). Pain at rest decreased mean 3 (SD 2.5), and pain in activity decreased mean 5 (SD 3) at 3 months followup. 3 trapeziums fractured intra-operatively, 1 trapezium necrotized and was revised with trapeziectomy, and 2 patients had intraprosthetic dislocation of the dual-mobility liner. PE wear was linear until 1 years follow-up (figure 1).

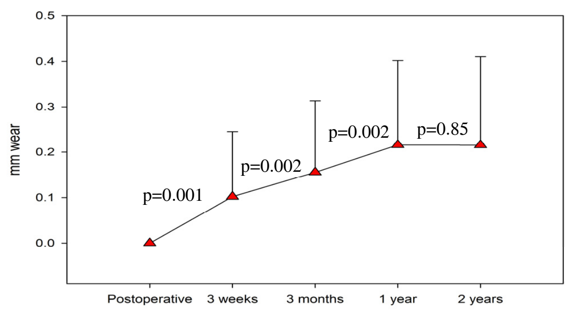

Figure 1: Mean (SD) PE wear in proximal cup direction.

CONCLUSIONS

Moovis Elektra cup fixation was acceptable for most implants (85%) up to 2 years followup, and only 1 cup was revised early due to osteonecrosis. PE wear increased linearly until 1 year and was above the osteolysis threshold for hip implants, which may cause concern for risk of future PE liner revisions. Overall, results for the Moovis cup are promising and better compared to most other available cup designs.

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INDUCIBLE MICROMOTION AND CONTACT POINT PROVIDE INSIGHT INTO THE MIGRATION OF PEGGED GLENOID IMPLANTS

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INTRODUCTION
Aseptic loosening of cemented pegged glenoid components is a common cause of failure in total shoulder arthroplasty (TSA). Although proposed to be related to eccentric loading and micromotion of the glenoid or "glenoid wobble" [1], there have been no studies demonstrating such movement in-vivo. Radiostereometry (RSA) has been used to assess glenoid implant migration over time in previous studies, however the study of inducible movement by differential active loading, has not previously been reported [2,3].
The objective of this study was to determine whether movement of the glenoid under load could be measured reliably, and whether we could deduce the contact point of the humeral implant with the glenoid bearing surface. In addition we examined whether overall migration of the glenoid is associated with either inducible movement of the glenoid or humeral contact point.

METHODS
Recruited patients underwent primary TSA with a cemented pegged Affinis glenoid and a ceramic bearing with press fit stemless humeral component (Mathys, Switzerland). Tantalum markers were inserted into the scapula at surgery and into the glenoid implant during manufacture. RSA was carried out supine using AdoraRSA (NRT, Denmark) with Canon CXDI50C detectors and calibration box 41 (RSA Biomedical AB, Sweden). Patients were imaged supine with arm relaxed at 1, 6, 13, 26, and 52 weeks. In addition they were imaged with the shoulder abducting against a force of 12N at the wrist at 13, 26 and 52 weeks. Mean error threshold of 0.2mm was used. Precision was determined from repeat examinations of loaded and unloaded examinations at 13 weeks. Movement of the implant was determined relative to the scapula. In addition the contact point of the humeral head on the glenoid was determined using CAD models to reconstruct the glenoid implant surface and a geometric model of the humeral head. The accuracy of this method was tested by fixing markers to the humeral and glenoid bearing surface of test implants in-vitro to determine the uncertainty in surface estimation.

RESULTS AND DISCUSSION
11 patients have been recruited with follow up between 6 and 52 weeks. The 95% precision limit for implant movement was 0.1mm for translation and 0.5 degrees for rotation (n=10 patients). The dominant implant movement was rotation posteriorly and superiorly for both migration (figure 1) and induced loading (figure 2). At 26 weeks the maximum total point motion of the peg markers reached a mean of 0.35mm for inducible motion, and 0.7mm for migration. The rate of movement reduced by one year. Inducible posterior tilt at 13 weeks was correlated to posterior offset of the head and to posterior offset of the contact point (figure 3a). Superior inducible movement correlated to a superior contact point. Inducible posterior migration at 13 weeks was associated with overall posterior migration (figure 3b).
Measurable migration and inducible movements of the glenoid was observed. The different patterns for each patient can in part be understood by the different contact points on the glenoid. Currently there is little evidence linking migration to clinical outcome for glenoid implants. Indeed all the patients in this study are doing well clinically, and the rates of migration and inducible movement are decreasing at one year.

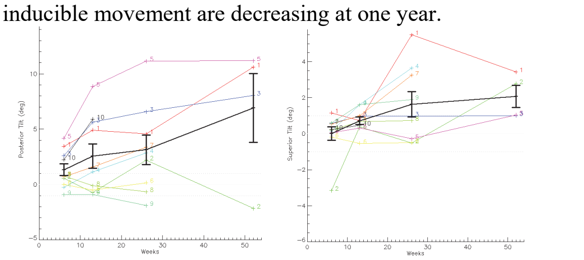

Figure 1. Migration. (a) posterior and (b) superior tilt. Coloured lines patients, thick black is mean and standard error.

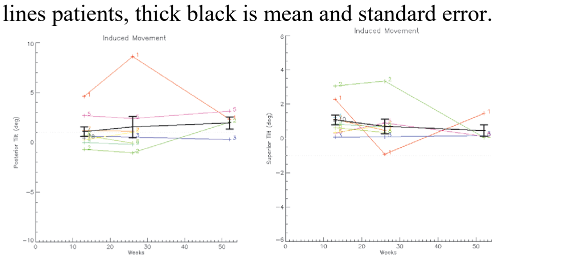

Figure 2. Induced movement. (a) posterior and (b) superior tilt.

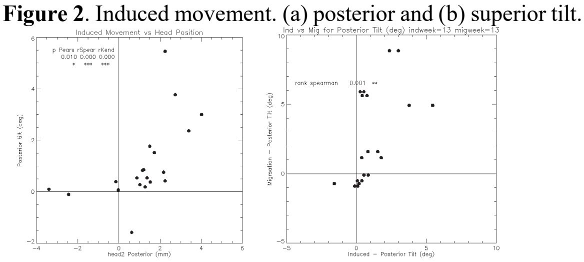

Figure 3. Correlation of posterior induced movement at 13 weeks to head position (a), and to migration (b).

CONCLUSIONS
Inducible movement and contact point estimation has not been previously reported for the glenoid. We have shown they can be measured reliably, and in this study both measurements have provided useful insight to the individual migration of the glenoid implants.

ACKNOWLEDGEMENTS
This study was funded by Mathys (Bettlach, Switzerland).

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   Mathys , (Switzerland) funded Aberdeen University (to which the authors are affiliated and or employed by) to carry out investigator led research into the Affinis Shoulder replacement

INFLUENCE OF ANTEROLATERAL LIGAMENT ON KNEE LAXITY DURING FLEXION-INTERNAL ROTATION. A BIOMECHANICAL CADAVER STUDY USING DYNAMIC RADIOSTEREOMETRIC ANALYSIS.

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INTRODUCTION

Anterior cruciate ligament (ACL) tear is one of the most common ligament injuries in the knee. ACL reconstruction still remains unable to replicate native knee kinematics.

The re-description of the anterolateral ligament (ALL) [1] in the recent years caused renewed interest in extra-articular lateral reinforcement to reduce rotational knee joint laxity as a supplement to intra-articular ACL reconstruction. Research on the stabilising effect of ALL on the knee joint has mainly utilised static evaluation methods, which do not mimic the dynamic pivot-shift-like movement that has been shown to correlate with symptomatic functional instability.

Therefore, the purpose of this ex vivo study was to evaluate the contribution of the ALL on knee laxity during a controlled pivot-like dynamic movement.

METHODS

Examinations were performed on eight fresh-frozen human donor legs (from 2 F and 2 M) that included the foot, knee and hemipelvis. The donors' age ranged from 58 to 94 years, and they had no history of knee-associated fractures or soft-tissue lesions.

Subject specific femur and tibia bone-models was generated based on Computed Tomography scans and was each assigned to local anatomical reference systems using a fully automated method [2].

A customized motored fixture was designed to simulate pivot-like dynamic movements on the specimens by applying internal rotation (4 Nm of torque at full knee extension) to the foot and lower leg at motion initialisation. This rotation was maintained during knee flexion (0˚ to 60˚). We tested the cadavers in five successive ligament situations: intact, ACL lesion, ACL+ALL lesion, ACL reconstruction, and ACL+ALL reconstruction.

Stereo radiographs of the knee motion was recorded using the AdoraRSAd system (Nordisk Røntgen Teknik, Denmark) with 10 Hz sampling frequency. Model-Based RSA (RSAcore, Leiden, MBRSA, v.4.02) was used to fit the bone models by contour detection in each frame. [3] To ensure clinical relevant results the kinematics were standardised in accordance with the terms introduced by Grood and Suntay.

Statistical tests were conducted using a mixed model to take into account repeated measures on the cadaver, leg pairs and ligament situations.

RESULTS AND DISCUSSION

For the entire motion, the ACL+ALL lesion increased knee internal rotation by 2.54˚, anterior translation by 1.68 mm, and varus rotation by 0.53˚ (p<0.005). The adjuvant ALL reconstruction reduced anterior translation (p=0.003) and varus rotation (p=0.047) in the knee joint compared with ACL+ALL deficient knees. We evaluated knee laxity in 10° ranges of knee flexion and, in comparison with the intact knees, we found larger internal rotation (p<0.001) and larger anterior translation (p<0.045) for ACL+ALL lesions, when the knee flexion angles were below 40˚ and 30˚, respectively. Combined ACL+ALL reconstruction did not completely restore native kinematics at flexion angles below 10˚ for anterior translation and below 20˚ for internal rotation (p<0.035).

CONCLUSIONS

In conclusion, combined ACL and ALL reconstruction recreate internal rotation and anterior translation knee laxity similar to that of the ligament intact knee, except in knee flexions between 0˚ to 20˚.

ACKNOWLEDGEMENTS

This project was supported by the Innovation Fund Denmark (grant number: 69-2013-1), Civilingeniør Frode V. Nyegaard Hustrus Foundation, Ortopædkirurgisk Forskningsfond in Aarhus Denmark, A.P Møller Fundation – Fonden til Lægevidenskabens Fremme, Grosserer L. F. Foghts Fond, Helga og Peter Kornings Fond. The Danish Council for Independent Research supported M. S. Andersen under grant number DFF-4184-00018.

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THE UTILIZATION OF RADIOSTEREOMETRIC ANALYSIS IN ANIMAL SURROGATES OF HUMAN ORTHOPAEDIC DISEASE

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INTRODUCTION

Extrapolating the results obtained from animal models of human orthopaedic disease is often problematic. Historically, researchers have relied on data obtained from mechanical testing, radiology and histology from which to draw conclusions about the 'possible performance' of a given device or material in human clinical practice. As a means of addressing concerns about 'clinical relevance', we have utilized RSA in a number of animal studies.

This study presents four different applications of RSA to accurately measure clinically relevant parameters including: **1)** migration of a cemented femoral stem in an ovine model of impaction grafting; **2)** migration of the femoral head in an ovine hemiarthroplasty model to represent cartilage wear over time; **3)** stability of anterior cruciate ligament following reconstruction to compare metal and bioresorbable screw stability; **4)** rotational stability of a tibial segmental defect model to assess torsional stiffness.

METHODS

Skeletally mature Merino sheep were used in all four studies. Tantalum markers were implanted intraoperatively to each segment of interest. All RSA examinations were taken using dual simultaneous radiographs above a calibration cage (Cage 43, RSABiomedical, UmRSA, Sweden). Subsequent pairs of radiographs were analysed using UmRSA software (v6.0, RSABiomedical). In vivo imaging was performed under general anaesthesia at the time of operation and then again at subsequent time points. Custom-made 'rigs' were used to position the sheep appropriately for RSA exams. Study 4 required a special torsion loading jig to be designed to apply varying progressive loads while not obstructing RSA images.

Figure 1: RSA examination set up in animal theatre

RESULTS AND DISCUSSION

Study 1) 14 sheep randomly received either bone graft irradiated at 15kGy or non-irradiated bone graft as part of a femoral impaction grafting hemiarthroplasty model. All stems had tantalum markers attached by the manufacturer to allow RSA analysis. Stem migration, for each of two different treatments, appeared to plateau at 4-6 weeks following implantation.

Study 2) The rate of acetabular cartilage wear increased through 6 weeks post-implantation (mean 0.5mm). Thereafter, the rate of wear remained comparatively unchanged which was confirmed by visual inspection of retrieved specimens [1].

Study 3) There was no improvement in biomechanical properties observed for either the metal or bioresorbable screws with mesh as evaluated by load to failure or anterior translation in this cadaveric model [2].

Study 4) Rotations measured using RSA under different loads were able to be extrapolated into torsional stiffness of two treatment groups. *Ex vivo* testing of tibia will be compared to CT scans taken of the same tibia *in vivo*. The stiffness of the contralateral tibiae will be used as a control measure of fracture healing. Identifying an amount of torsional stiffness in this model will allow future studies to accurately monitor the progression of fracture healing *in vivo*.

CONCLUSIONS

RSA and DLRSA have successfully provided quantitation of wear, migration and rotation in several different animal models of human orthopaedic disease. This has allowed clinicians to extrapolate the data to that with which they are familiar in the human patient.

ACKNOWLEDGEMENTS

These studies were supported by grants from the NHMRC, Australian Orthopaedic Association, Smith and Nephew, Memphis and the US Department of Defense.

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DAY 3

KEYNOTE 5 – Prof Rob Nelissen

THE VALUE OF RSA AND REGISTRIES FOR PATIENT SAFETY.

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Using RSA as a method of early (premarketing) assessment of implant performance is substantial. This potential is currently being recognized by various regulatory organs on different levels. The NICE (National Institute for Health and Clinical Excellence) guidelines of 2000 (United Kingdom) require adequate long-term clinical data for hip prostheses and indicate that RSA is a promising technique that may be an alternative for long-term follow-up studies. However, additional proof of its predictive value for future loosening is demanded. The Netherlands Orthopaedic Association has adopted in its new guidelines for hip prostheses that any new hip prosthesis that is being considered for (commercial) introduction to the Dutch market has to pass a phased introduction. This phased introduction includes mandatory RSA studies even before larger clinical trials can be initiated. A phased introduction of new implants or related developments has been proposed by several authors. The stepwise introduction described by Faro and Huiskes in 1992 and again by Malchau 1995 may be the most widely known proposal for high quality new medical device introduction. This phased introduction has evolved to a several proposals ensuring high Quality meiodcal devices and patient safety. A possible proposal could for this step wise introduction could be: (1) preclinical tests, (2) RSA evaluation of implant-bone fixation, (3) large clinical trials, nested within regional or national registries, (4) continuous surveillance in national registries. If a new articulation concept is launched, one might add to phase 2, phase 2B locoregional evaluation of surgical site (i.e. MRI or CT) and even phase 2C analysis of systemic effects of new articulation material. In this proposal for the orthopaedic toolbox for new implants, In this way, advantage is taken of the great potential of RSA regarding patient protection in the introduction of new implants.

Implementation of this phased introduction of new prostheses, with RSA as an early qualitative (warning) tool, will establish safer and more effective patient care, by reducing the revision load at an earlier timer point.

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DAY 3

PODIUM 3 – Joint Session

IMPLANT-RELATED REVISION OF PRIMARY TOTAL HIP REPLACEMENT AT 10 YEAR FOLLOW-UP OF A RANDOMISED TRIAL OF ARTICULATION SIZE

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INTRODUCTION

At total hip replacement (THR), the most commonly used articulation is a metal femoral head on a highly cross-linked polyethylene (XLPE) liner [1]. The aim of our study was to examine the incidence of dislocation and implant-related revisions among primary total hip replacement patients with 10 year follow-up in a randomised controlled trial which compared 28 and 36 mm metal on highly cross-linked polyethylene articulations. The secondary aim was to compare the wear of 28 and 36 mm articulations.

METHODS

The original randomised controlled trial included 557 patients undergoing primary total hip replacement randomised to either a 28 or 36mm articulation intra-operatively [2]. The current study followed up all 328 patients who were treated within Australia. Hospital records of revision data were cross matched against the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). In addition, patient case notes were reviewed and all dislocations were confirmed radiographically, as shown in Figure 1. Linear wear was measured for all patients on plain AP pelvis radiographs using PolyWare Pro 3D Digital Software (Rev 5, Draftware Developers, Vevay IN, USA).

RESULTS AND DISCUSSION

320 of the 328 primary THRs undertaken in Australian hospitals as part of the original RCT were successfully cross-matched with the AOANJRR's data (to December 2014).
At 10 year follow-up dislocation had occurred in 9 (5%) 28 mm and 2 (0%) 36 mm articulations, as shown in Table 1. Three of the nine hips with 28 mm articulation experienced recurrent dislocations. At 10 year follow-up 14 of 320 (3% 28 mm, 6% 36 mm) hips had undergone revision. The reasons for revision were dislocation in 3 (2%) 28 mm and 0 (0%) 36 mm; infection in 1 (0%) 28 mm and 2 (1%) 36 mm; periprosthetic fracture in 0 (0%) 28 mm and 3 (2%) 36 mm; loosening/lysis in 1 (0%) 28 mm and 2 (1%) 36 mm; liner fracture in 2 (1%) 36 mm articulations.

Figure 1: AP Pelvis Radiograph of a 28mm articulation confirming dislocation of a primary left primary THR within 1 month after surgery.

The mean annual linear wear rate between one and ten years follow-up was 0.04 mm/yr for both 28 and 36 mm articulations (p=0.48).

CONCLUSIONS

This study shows that a 36 mm metal on highly cross-linked polyethylene articulation used at primary total hip replacement reduces the incidence of dislocation and the need for revision for dislocation at 10 year follow-up. Importantly the use of a larger articulation did not increase the mean annual linear wear rate at 10 year follow-up.

ACKNOWLEDGEMENTS

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Table 1: Prevalence of dislocation by articulation size.

Articulation Size	n	Length of follow-up after Primary THR		
		Within 1 year	Between 1 and 10 years	Within 10 years
28	164	7	2	9 (7%)
36	156	1	1	2 (0%)

EARLY PROXIMAL MIGRATION OF CEMENTED CUPS AND THE OCCURRENCE OF ASEPTIC LOOSENING

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INTRODUCTION

Early migration of cemented cups can predict later aseptic loosening and revision [1]. So far longterm follow up of cups studied with use of radiostereometric analysis have been restricted to few cases. We therefore compared early proximal cup migration with later occurrence of radiological loosening as well as revision for aseptic loosening of the cup including all primary cases performed at our department from 1991 and onwards.

METHODS

262 hips (254 patients) participated in 5 randomized radiostereometry (RSA) studies at our institution. To be included RSA follow up to at least 2 years and case records should be available. After these exclusions 227 hips remained. All hips received total hip arthroplasty (THA) with cemented cups. The varying implant designs and cement types are listed in Table 1 along with patient demographics.

RSA examinations were performed postoperatively and then after 6 months, 1 and 2 years. In addition, one of the authors (JK) analyzed the latest available radiograph for every hip, regardless if revised or not, and classified cups and radiologically fixed or loose. Cups deemed loose had a complete radiolucent line on either the AP or lateral view or both. Cup revisions were identified in patient records and included if aseptic cup loosening was the main reason or if the cup was found loose intraoperatively. Radiographs were unavailable for 10 hips. Median follow up was 15.3 (2-23) years.

The association between proximal cup migration at 6 months, 1 and 2 years and later cup loosening or revision for aseptic cup loosening was analyzed with Cox regression analysis adjusted for age at surgery and gender.

Table 1: Patient demographics and THA/cement types of 227 hips included in the study.

Age at surgery[1] (years)	65 (31 - 79)
Gender[2] (female / male)	139 / 88
Diagnosis[2] (primary OA / secondary OA / NA)	200 / 25 / 2
Cup type[2]	
Charnley Elite	22
Lubinus IP	76
Weber PE	30
Weber XLPE	27
Reflection	72
Cement type[2]	
Palacos	193
Cemex-F	21
Boneloc	13
Stem [2]	
Cemented	208
Uncemented	19

[1] median (range), [2] number of hips

RESULTS AND DISCUSSION

Proximal cup migration at 2 years was associated with radiological cup loosening (HR=27, 95%CI: 5 - 154, p<0.001; 217 hips, 46 loose cups, median follow-up 13 years, range 2-24) and revision for cup loosening (HR=22, 95%CI: 3 - 161, p=0.003; 227 hips, 30 revisions, median follow-up 15 years, range 2 - 23). However, 30 % (14/46) of radiologically loose cups had migrated less than 0.15 mm at 2 years.

CONCLUSIONS

Proximal cup migration at 2 years can predict both radiological cup loosening and revision for aseptic cup loosening. However almost 1/3 of radiologically loose cups had a low proximal migration at 2 years, suggesting two patterns of loosening, one caused by poor early fixation and a second one caused by an osteolytic process with progressing radiolucencies, finally ending up in mechanical loosening as reflected by a late initiation of migration.

ACKNOWLEDGEMENTS

Institutional support was received from Zimmer, Biomet, Sulzer and Link.

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THE DIAGNOSTIC PERFORMANCE OF ACETABULAR MIGRATION TO DETECT ASEPTIC LOOSENING AFTER PRIMARY TOTAL HIP ARTHROPLASTY RESULTS

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INTRODUCTION

Migration measured on radiographs has often been used to diagnose loosening of acetabular components used at primary total hip replacement (THR). The amount of migration used to diagnose loosening varies up to 6mm in the literature because no study has compared the migration threshold to confirmed intra-operative loosening status at the time of revision [1]. EBRA-Cup is the most sensitive method to measure acetabular component migration retrospectively [2].
This study aimed to determine the diagnostic performance of proximal rotation and sagittal rotation of uncemented acetabular components after primary THR to detect aseptic loosening.

METHODS

Surgeons have been prospectively recording the loosening status in the operation record for each hip revised at our institution since 1985. Case notes were reviewed for all patients who underwent primary THR at the Royal Adelaide Hospital and were subsequently revised and/or reoperated on between 1985 and 2016.
121 hips had the acetabular component confirmed to be loose or not loose documented in the operation record at the time of revision/reoperation. 44 hips were excluded because they were revised within 3 months which is the minimum time required for bone ingrowth [3].
The acetabular component migration (proximal translation and sagittal rotation) to revision surgery was measured retrospectively using EBRA-Cup analyses of AP pelvis radiographs for each hip included in the study. Hips were divided into two groups: Group A, 58 components found not loose at revision (mean time to revision 75mths; range 3 to 311) and; Group B, 19 components found loose at revision (mean time to revision 148mths; range 10 to 245).
Migration thresholds were then calculated using xxx to determine the amount of proximal translation and sagittal translation to diagnose the component as loose or not loose.

RESULTS AND DISCUSSION

The mean proximal migration of Group A (0.6mm) was significantly lower than Group B (6.1mm). The mean sagittal rotation of Group A (1.1 degrees) was significantly lower than Group B (14.9 degrees).

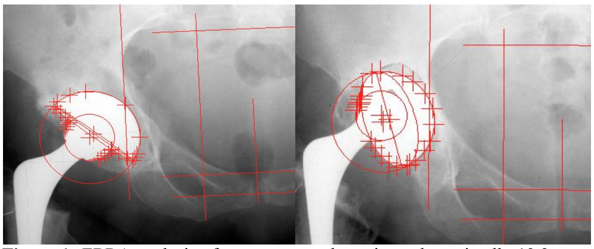

Figure 1: EBRA analysis of a component that migrated proximally 13.2mm, rotated 34.8degrees and was found to be loose when revised at 151 months. (a) AP Pelvis radiograph taken within the first postoperative week post primary THR, (b) AP pelvis radiograph taken prior to revision surgery.

A threshold of 2.6mm of proximal translation had a sensitivity of 98% and a specificity of 71%. A threshold of 2.5 degrees of sagittal rotation had a sensitivity of 98% and a specificity of 82%. Both of these thresholds were found to be good diagnostic tests (area under the ROC curve=0.8 and 0.9 for proximal translation and sagittal rotation respectively).
All studies examining migration in primary acetabular components in the literature to date did not have confirmed intraoperative loosening status at revision surgery [4, 5].
Limitations of this study are the varied types of cementless acetabular components with different ingrowth designs which had been implanted over a long period. Several of the components investigated are no longer in clinical use. This problem will be encountered in any long-term study that spans more than 30 years.

CONCLUSIONS

This is the first study using confirmed intraoperatively loosening findings to determine that proximal migration and sagittal rotation are both good diagnostic tools to detect aseptic loosening of uncemented acetabular components prior to revision surgery.

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ASSESSING THE INFLUENCE OF CUP MATERIAL PROPERTIES ON THE PRIMARY STABILITY OF CEMENTLESS ACETABULAR CUPS USING FINITE ELEMENT MODELLING

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INTRODUCTION

Primary stability of an acetabular cup allows bone ingrowth into its porous surface and, in turn, long-term success of the total hip replacement. Micromotion and interfacial gaps at the bone-implant interface are measures of primary stability for the cementless acetabular cup [1].

The challenge during the design and development of a new acetabular cup is assessing its likely performance in a diverse population prior to clinical trials. Currently, the majority of finite element (FE) studies typically assess changes to a design on a single hip joint [2]. There is a need to account for the variations that exist between individuals to give an indication of the spread in the primary stability in the population. However, generating and analysing a population of subject-specific FE models has a significant time cost. Using a small representative subset of subjects may provide an approximation of the spread in primary stability in the population for comparing minor design changes.

The aim of this study was to compare the variation in polar gap and micromotion of an acetabular cup design with different material properties in a representative set of FE hemipelvis models.

METHODS

CT scans of 11 subjects, 6 males and 5 females, (age 73 years ± 12, bodyweight 76 kg ± 21) that were representative of a larger cohort [3] were used to generate subject-specific FE models. Heterogeneous bone material properties were assigned based on CT greyscale information. All materials in the models were assumed to be linear elastic.

For each hemipelvis, explicit FE analyses were performed (ABAQUS) using a Titanium (E = 115 GPa) and a Cobalt-chrome (E = 200 GPa) Pinnacle ® acetabular shell (DePuy-Synthes Inc). In each case, the shell was implanted into the acetabulum, using displacement control, until it was fully seated and then allowed to spring back to an equilibrium position. Afterward, the joint reaction forces from a gait cycle were scaled to the subject's bodyweight and applied in 50 loading increments.

Polar gap was measured between the pole of the cup and bone at its equilibrium position following insertion. Micromotion at the bone-implant interface was calculated by tracking the relative displacement of interfacial cup-bone node pairs. The composite peak micromotion (CPM) was taken for each interfacial cup node as the highest relative displacement experienced at any point during the loading cycle [4].

RESULTS AND DISCUSSION

The polar gap in the Titanium cup had a median value of 499 µm and an interquartile range of 455 to 483 µm. The median polar gap in the Cobalt-chrome cup was 518 µm and an interquartile range was 500 to 640 µm (Figure 1). The results suggested there was an increase in polar gap for the Cobalt Chrome cup the difference was not significant.

The 95th percentile CPM in the Titanium cup had a median value of 228 µm and an interquartile range of 76 to 318 µm in the 11 subjects. Meanwhile, the 95th percentile CPM for the Cobalt-chrome cup had a median value of 260 µm and an interquartile range of 97 to 260 µm (Figure 1). There was no difference in 95th percentile CPM between cups.

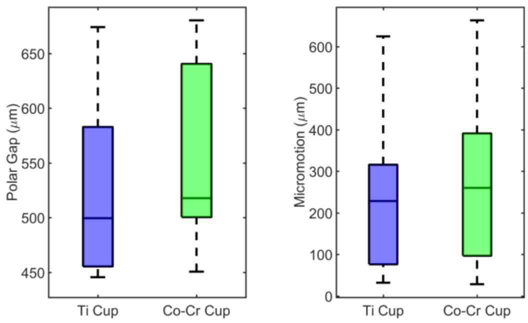

Figure 1: Boxplots of the polar and gap and the 95th percentile Composite Peak Micromotion (CPM) for the Titanium (blue) and the Cobalt-chrome (green) Pinnacle cup in the 11 hemipelvis models.

CONCLUSIONS

Increasing elastic modulus of the cup did not increase the level of micromotion in the representative set of subjects examined. There was some indication of increased polar gap after insertion in the cup with the higher elastic modulus but the difference was not clinically significant. Using a smaller, representative subset of patients provides an approximation of the changes in primary stability for minor design changes early in the development phase of a new cup.

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RANDOMIZED CONTROLLED STUDY COMPARING THE SHORT COLLUM FEMORIS PRESERVING (CFP) AND THE CORAIL PROSTESIS: PRELIMINARY RESULTS

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INTRODUCTION

The concept of femoral neck preserving hip replacement is intended for the young and active patients. By preserving proximal bone load, the transmission to the proximal femur is supposed to improve and future revision surgery would be facilitated. So far the clinical documentation of the Collum Femoris Preserving stem indicates a stable fixation and good short- and intermediate terms results on durability [1-3]. We speculated that a more conservative resection of the femoral neck could lead to better clinical outcomes compared to a conventional stem. We therefore compared the clinical outcomes and the fixation between a short stem and a stem with a classic design.

METHODS

83 patients were included in our randomized controlled trial where patients either received a Collum Femoris Preserving (CFP) stem or a Corail hip stem. All patients recieved the same type of uncemented cup. Clinical outcomes were assessed, plain radiographs were studied and the early migration was measured using radiostereometric analysis. Follow-up was obtained for 1 year.

RESULTS AND DISCUSSION

All clinical outcomes improved after surgery. The Harris Hip score increased from 52 to 93 in the CFP group and from 53 to 98 in the Corail group ($p < 0.001$). At one year the clinical outcomes (Oxford Hip Score, Harris Hip Score, EQ-VAS, satisfaction VAS and pain VAS) did not differ between the two groups (p= 0.05 – 1.00). The radiographic measurements showed that the CFP stem preserved the neck of the femur. The medial-lateral migration of the femoral head centre did not differ (p= 0.40). The mean subsidence showed the same trend (Figure 1). The Corail stem showed increased posterior displacement after one year, but no difference was found between the absolute translations in the anterior-posterior direction. None of the hips were revised. One patient in the Corail group did not attend at one year.

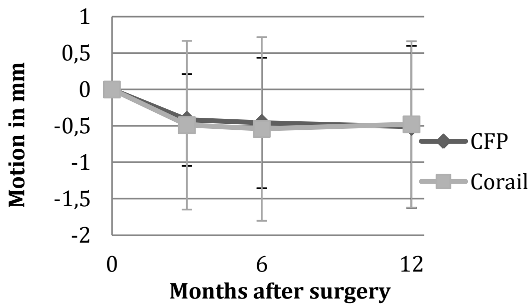

Figure 1: Subsidence of the stem in millimeters up to 12 months after surgery. Graph represents mean value +/- standard error.

CONCLUSIONS

The outcomes after one year were good to excellent. In the short time perspective we could not find any difference in clinical outcomes and stem fixation, indicating that there are no obvious advantages to the use of the CPF stem. It remains to be seen whether the bone preservation associated with use of CFP prosthesis will ease future revision.

ACKNOWLEDGEMENTS

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   This study was supported by LIMA, Italy and LINK, Germany.

AN RSA RCT COMPARING TWO CEMENTED FIXED BEARING KNEE DESIGNS

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INTRODUCTION

To improve survival of implants and to achieve better clinical outcome, orthopaedic companies constantly design new prostheses by adapting the design parameters or adding completely new features.
The Cemented PFC Sigma Fixed Bearing Cruciate Retaining Knee System is a knee replacement with a good clinical track record, good survival rates [1] and minimal early migration as measured with RSA [2].
The Cemented ATTUNE™ Fixed Bearing Cruciate Retaining Knee System is designed to provide better range of motion and address the unstable feeling some patients experience during everyday activities, such as stair descent and bending.
Complying with the phased introduction of new implants, it is important to compare the migration of this new implant with an established and well performing Total Knee Arthroplasty (TKA) system in a Randomized Clinical Trial (RCT) [3].
The objective of this study is to accurately assess and compare migration, measured by RSA, clinical and radiological outcome and patient reported outcomes of these two TKA systems from DePuy Synthes, Warsaw, Indiana, USA.
This abstract presents the preliminary one year results. At the time of the conference, most of the 2 year results will be available and presented.

METHODS

In this single-blind trial, 74 patients were randomized to receive either the ATTUNE™ Knee System or the PFC Sigma Knee System (control group). The study population consists of patients with symptomatic osteoarthritis of the knee scheduled for TKA at the Department of Orthopaedics, Haaglanden Medical Center, The Hague, The Netherlands. Annually about 300 TKA procedures are performed in this department, of which about 90% is osteoarthritis (OA) and 10% other indications.
RSA measurements using a standard uni-planar RSA setup were done directly post-op, and at 3, 6, 12 and 24 months post-op. Patient Reported Outcome Measures (PROMS) were collected pre-operative and at the same post-op time points.

RESULTS AND DISCUSSION

Mean (SD) age of the patients was 69 (9) years, BMI was 28 (4) kg/m^2. No differences between both groups were observed regarding KOOS, EQ5D and NRS pain scores up to one year after surgery. Migration results, transformed to a right side knee, at one year post-op are presented in Table 1. A linear mixed model fit of the migration parameters using the patient as random effect and group*time (Attune versus PFC) as fixed effects revealed that the difference between Attune and PFC femur Medial-Lateral translation (Tx) and Axial rotation (Ry) at 12 months are significant (Table 1). For the tibia no significant differences between Attune and PFC were found.
Other results, including the two year results, will be presented at the conference.

CONCLUSIONS

No significant differences in MTPM, clinical data and PROMS were found between the ATTUNE™ and PFC Sigma Knee Systems during one year follow-up. As for fixation, the ATTUNE™ seems to well performing. As for clinical outcome, larger clinical studies are necessary to evaluate range of motion, PROMS, and stability sensation of patients. For the latter, a gait analysis will be needed.

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Table 1: One year migration results in mm/deg (Mean (SD)).
Tx = Medial-Lateral Translation, Ty = Distal-Proximal Translation, Tz = Posterior-Anterior Translation
Rx = Anterior Posterior Tilting, Ry = Axial-Rotation, Rz = Medial-Lateral Tilting

	MTPM	Tx	Ty	Tz	Rx	Ry	Rz
Attune Femur	1.11 (0.63)	0.11 (0.30)	0.15 (0.21)	-0.11 (0.62)	0.26 (0.67)	-0.22 (0.57)	0.09 (0.32)
PFC Femur	1.36 (0.84)	-0.02 (0.35)	0.20 (0.25)	-0.17 (0.80)	0.51 (0.79)	0.19 (0.69)	0.04 (0.31)
Attune Tibia	1.19 (0.62)	-0.06 (0.28)	0.04 (0.22)	-0.25 (0.61)	-0.35 (0.80)	0.01 (0.90)	0.10 (0.34)
PFC Tibia	1.26 (0.71)	-0.09 (0.54)	0.02 (0.20)	-0.10 (0.62)	-0.22 (0.77)	0.07 (0.85)	0.02 (0.55)

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DePuy paid for the costs of this investigator initiated study.

CEMENTED *VS* UNCEMENTED FIXATION OF A CRUCIATE RETAINING FEMORAL COMPONENT IN TOTAL KNEE REPLACEMENT OF PATIENTS YOUNGER THAN 60 YEARS

A prospective randomized controlled RSA study with 10-years follow-up

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INTRODUCTION

The optimum mode of fixation of the femoral component in total knee replacement (TKR) is still uncertain, especially in younger patients. Results in the literature are varying. In a previous report we have shown no differences of migration or clinical results between cemented and uncemented fixation of the NexGen CR TKR in a 2 year RSA study in patients younger than 60 years [1]. In this study we report the results of this patient cohort followed for 10 years.

METHODS

41 consecutive patients (41 knees) younger than 60 years with primary osteoarthritis (OA) or OA secondary to meniscal and/or ligament injuries underwent TKR using the NexGen Option CR TKR. Randomization was performed intraoperatively after the femoral cuts had been made. For the radiostereometric analysis (RSA) the femoral components were equipped by the manufacturer with four tantalum beads encased in titanium rods which were attached to the anterior and posterior parts of the component.

RSA examinations were done at 3, 12, 24 months, and 10 years, with the patient lying supine using a biplanar calibration cage. Analysis was done using UmRSA software v 6.0. Rotations around the 3 cardinal axes, MTPM and translations of the centroid of the 4 implant markers were analyzed

RESULTS

22 patients received a cemented and 19 patients an uncemented femoral component. At 10 years 18 cemented and 16 uncemented implants could be analyzed. Losses up to 10 years, A): cemented group: deceased 1, moved abroad 1, revised due to instability 1, stroke 1; B): uncemented group: revised due to infection 1, deceased 1, too ill to attend 1. There were no revisions because of loosening.

At 10 years, rotations around the y (vertical) and z (sagittal) axes were significantly larger in the uncemented group ($p = 0.007$-0.035) as well as translation of the centroid along the vertical axis ($p=0.024$), whereas for the other parameters of migration there were no statistically significant differences between the groups. The pattern of migration up to 2 years did not differ. However, between 2 and 10 years the uncemented displayed increasing migration (Figure 1) whereas the cemented continued to be stable.

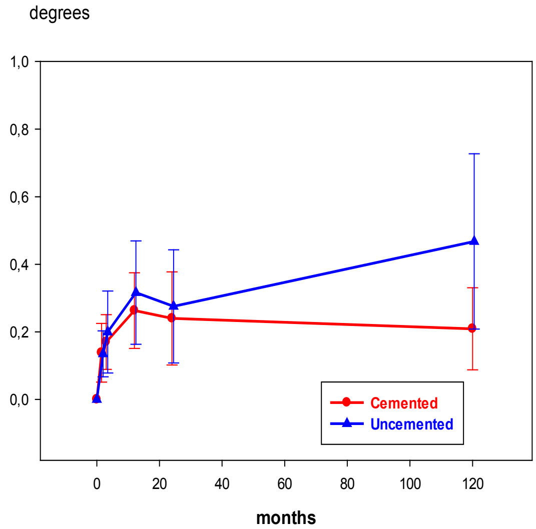

Figure 1: Absolute values of rotation around the z axis (mean, ± 95% CI)..

DISCUSSION

The patterns of migration of the cemented femoral implants up to 10 years indicate a good long-term prognosis regarding fixation. The migration patterns of the uncemented femoral implants do not show this advantage regarding long-term fixation, probably due to a too low porosity, a too small pore size, and insufficient coefficient of friction of the titanium fiber mesh coating.

ACKNOWLEDGEMENTS

This study was partially funded by Zimmer-Biomet

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   The study was partially funded by Zimmer Biomet

Pseudotumor development around primary metal-on-metal THRs: the 'at risk' geneotype

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INTRODUCTION

Metal-on-metal (M-o-M) bearing surfaces were once touted as the future of primary total hip replacement (THR), but their once widespread use has fallen dramatically following the emergence of overwhelming evidence demonstrating unacceptably high premature implant failure rates. The innate immune response to generated particulate metal wear debris has been shown to lead to aggressive peri-articular tissue destruction, currently known as Adverse Local Tissue Reactions (ALTRs). While the underlying pathophysiology of these so-called 'pseudotumours' is now well understood, the fundamental predisposing patient genetic risk factors have remained elusive. The aim of this research was to identify specific genes associated with the development of ALTRs in patients with *in situ* M-o-M THRs.

METHODS

A case-controlled, clinical-genotype correlation analysis of patients who received a large-head, primary M-o-M THR between 2005-2008 was performed. The minimum follow up period was 5 years. 'Case' subjects were patients that had undergone revision THR secondary to symptomatic ALTRs. 'Control' subjects were randomly selected asymptomatic patients, with no evidence of ALTRs on protocol-specific screening. Baseline demographics and high-resolution genotype (HLA Class-II) were collected for all patients. Pre-revision serum cobalt and chromium metal-ion concentrations were used for 'Case' subjects, while comparative samples were drawn at the time of final study follow-up for 'Control' subjects. The association between genotype and revision surgery secondary to ALTRs was determined, with gender as a covariate.

RESULTS AND DISCUSSION

Twenty-six 'Case' and 28 'Control' subjects were recruited. Groups were similar with respect to age at time of primary M-o-M THR (mean: 54.8 vs. 54.9 years, $p = 0.95$), serum cobalt ($p = 0.09$) and chromium ($p = 0.27$) concentrations. Mean time from primary M-o-M THA to symptomatic revision was 5.5 years (range: 1.1-9.5). An 'at risk' genotype was identified with a prevalence of 29.6% (16/54) among the entire cohort. Univariate testing found presence of the 'at risk' genotype (OR: 3.50, $p = 0.04$), and female gender (OR: 4.98, $p = 0.01$) to be positively associated with the need for revision surgery secondary to ALTRs. Adjusting for gender, the odds ratio for requiring revision was 6.1 times greater among patients with the *Risk Genotype* present, than patients without ($p = 0.01$).

CONCLUSIONS

Among patients with an *in situ* primary M-o-M THR, the findings of this study suggest that the presence of an identified 'at risk' genotype (HLA Class II loci) may be a strong, independent risk factor associated with the need for subsequent revision surgery secondary to symptomatic pseudotumour formation. To our knowledge, this work represents the first demonstrated link between patient-specific genotype and the predictive likelihood of ALTR development. Given the hypothesis-generating nature of this novel undertaking, confirmatory prospective clinical studies are required to further elucidate this correlation and to explore the clinical utility of targeted genetic screening in this specific orthopaedic population. This research may, however, represent a key contribution to the fundamental aetiologic understanding of metal-ion induced pseudotumour formation.

ACKNOWLEDGEMENTS

The authors would like to recognize the contributions of Ms. Raman Johal and Ms. Azarm Akhavien for their work in the consolidation and preparation of the samples and data utilized in this work.

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DAY 3

PODIUM 4 – Joint Session

ACCURACY OF MEASURING LARGE DYNAMIC MOVEMENTS WITH MARKER-BASED ROENTGEN FLUOROSCOPIC ANALYSIS

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INTRODUCTION

Aside evaluating implants' fixation RSA is used to study joint kinematics. The accuracy for measuring relative motions using a single-plane fluoroscope differs between different systems. With markers, the accuracies for rotations, in-plane translation and out-of-plane translational were approximately 0.1°– 1.0°, 0.1 mm and 0.7 mm – 0.9 mm respectively [1,2]. However, in these previous reports, the accuracy of large motion was not evaluated in real clinical situations. The images were obtained by a fluoroscope but the phantom was not moving, or, the phantom was moving, but the accuracy was assessed by calculating relative zero-motion between the segments placed on the same object of the phantom. The purpose of this study is to evaluate the accuracy of measuring relative large dynamic movements with marker-based RSA in clinical situations.

METHODS

Two representative clinical situations were tested in this study: hip flexion pictured in the anterior-posterior direction and knee flexion pictured in the lateral direction. In this study, we defined the accuracy as the reproducibility of measuring the same large movement. Two different sets of marker segments (large and small markers) placed on both sides of the joint were used. We calculated the difference between the results obtained by the two sets of marker segments. The examination was repeated 12 times and the mean and the standard deviation (SD) of the difference was calculated. We used MB-RSA (RSAcore).

RESULTS AND DISCUSSION

Accuracy is shown in Table 1. For the hip, most of the absolute values of the means and SDs in rotations were less than 0.1 in rotations. Accuracy in y-translation got worse as the flexion angle was increased. For the knee, relatively low accuracy was observed in the directions of the knee movement (z-rotation), although it was in-plane directions. The accuracy was the worst in z-translation in both the knee and the hip experiments (out of plane movement).

CONCLUSIONS

RSA is a useful tool to evaluate joint kinematics but care should be taken to place the joint correctly to perform the movement of interest in the best plane. Accuracy was affected by the flexion angle.

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Table 1: Accuracy of measuring the hip and knee movements.

	Angle		X	Y	Z	Rx	Ry	Rz
Hip	**30**	Mean	-0.0444	-0.0346	0.2212	0.0029	-0.0211	0.0164
		SD	0.0696	0.2429	0.6066	0.1075	0.0582	0.0318
	60	Mean	-0.0887	-0.2461	0.3902	-0.0274	-0.0693	0.0335
		SD	0.1132	0.3114	0.6262	0.0965	0.0600	0.0495
	90	Mean	-0.0474	-0.2965	0.1032	-0.0022	-0.0341	0.0187
		SD	0.1134	0.4311	0.6165	0.1033	0.0833	0.0651
Knee	**45**	Mean	0.0952	0.0886	-0.1275	-0.0079	-0.0160	0.0936
		SD	0.0710	0.0407	0.4340	0.0156	0.0141	0.0212
	90	Mean	-0.1339	0.0768	-0.4272	-0.0079	-0.0145	0.1089
		SD	0.1202	0.0721	0.4744	0.0161	0.0172	0.0298
	135	Mean	-0.2601	0.0453	-0.3453	-0.0494	-0.0080	0.1409
		SD	0.1790	0.0573	0.4884	0.0851	0.0426	0.0496
	160	Mean	-0.2715	-0.0309	-0.5014	-0.0705	-0.0103	0.1271
		SD	0.1783	0.1469	0.5326	0.1325	0.0444	0.0532

MUSCLE CONTRIBUTION TO SUPPORT DURING WALKING IN TRANSFEMORAL AMPUTEES

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INTRODUCTION

Muscle contributions to the vertical acceleration of the body centre of mass stance is required to maintain body support during ambulation [1]. Trans-femoral amputees have asymmetrical gait patterns compared to non-amputees [2]. This is due, in part, to the lack of ankle and knee muscles, which play prominent role in normal gait mechanics including body support, forward progression and mediolateral balance. As a result, amputees must use other muscle compensatory mechanism to be able walk. The aim of this study was to develop a 3D musculoskeletal model to evaluate for the first time the muscles that contribute to body support during walking in transfemoral amputees.

METHODS

One transfemoral amputee (age: 24 years, height: 1.68m, weight: 60.8kg) was recruited, and performed motion analysis experiments. Motion of the body was measured as the subject walked at their self-selected speed. This was achieved by tracking the positions of retro-reflective markers placed on the body using high-speed cameras (Vicon, Oxfordmetrics, UK), and performing inverse kinematics. Ground Reaction Force (GRF) data were simultaneously acquired from three imbedded force plates (Watertown, MA, USA). Kinematics and GRF data were filtered using low pass Butterworth with a cut-off of 6 Hz and 20 Hz, respectively.

A 3D muculoskeletal model of the amputee was developed in OpenSim and consisted of 8 rigid body segments, 23 DOFs, and 76 muscle actuators. The ankle and knee-spanning muscles of the amputated limb were removed from the model, while the insertion of rectus femoris was altered to simulate its surgical reattachment. The prosthesis was modelled in SolidWorks (Massachusetts, USA) to calculate the moment of inertia and center of mass properties, which were subsequently employed in the musculoskeletal model.

Muscle forces were calculated during walking using static optimization by decomposing the net joint moments calculated from inverse dynamics into discrete muscle actuator loads. Contributions of muscle to the vertical components of the GRF were determined using a pseudo-inverse GRF decomposition method.

RESULTS AND DISCUSSION.

In the contralateral limb, the gluteus medius and minimus were the primary muscles providing body support during early stance. The vasti and gastrocnemius muscles provided the majority of body support during mid and late stance, while soleus muscle was an important contributor during the entire stance phase (Figure 1). For the residual limb, the passive prosthesis properties had a great role in supporting the body throughout stance, while the adductor magnus and gluteus muscles displayed considerable contributions during mid-stance (Figure 2).

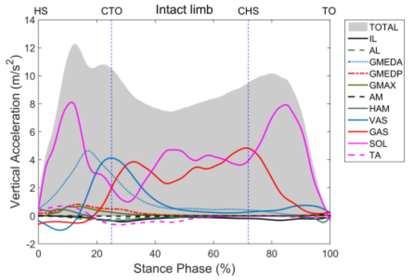

Figure 1: Muscles contribution to body support in the intact (contralateral) limb.

Symbol definitions are as follows. IL: iliacus + psoas; AL: adductor longus+ adductor brevis + pectinus + quadriceps femoris; GMEDA: gluteus medius and minimus in anterior and middle; GMEDP: gluteus medius and minimus in posterior; GMAX: gluteus maximus; AM: adductor magnus; Ham: hamstring; Vas: vastus; RF: rectus femoris; GAS: gastrocnemius; SOL: soleus; TA: tibialis anterior; HS: heel-strike; CTO: contralateral toe-off; CHS: contralateral heel strike; TO: toe-off.

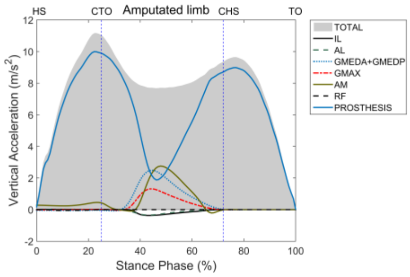

Figure 2: Muscle contribution to body support during stance in the amputated limb.

See Figure 1 for symbol definitions.

CONCLUSION

In transfemoral amputees, vertical support is predominantly generated by the prosthesis itself, with small contributions by the hip muscles. The extensors of the ankle, knee and hip generate the vertical support in the intact leg. The muscle function data identified in this transfemoral amputee during ambulation may be used to devise new rehabilitation programs and prosthesis design to improve gait.

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Polyethylene wear study on the non-cemented Triathlon CS total knee prosthesis.

Two year results of a randomised single centre RSA study.

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INTRODUCTION

Polyethylene wear and aseptic loosening are the most common long-term causes of failure of total knee arthroplasty [1,2]. Over the years development of polyethylene constructs in arthroplasty have shown an improved wear resistance. X3-polyethylene insert (Stryker Orthopaedics, Mahwah, USA) is Stryker's next generation polyethylene construct showing a theoretical and in vitro improvement of wear resistance. A first in-vivo clinical study [3] showed no mechanical failure or radiographic osteolysis. The primary objective of this study is to assess the in vivo wear of two randomised polyethylene inlay types, standard UHMWP (N2Vac) and highly cross-linked UHMWP (X3) by means of RSA analysis. The secondary objective is the assessment of prosthetic migration and clinical outcome after 2 years (and long term) of Triathlon Cruciate Substituting fixed bearing peri-apatite coated tibial and femoral components by means of RSA and patient reported outcome measures (PROMs). The third objective was to assess "inducible micro motion" of the tibial component**.**

METHODS

Prospective randomised single centre RSA study of 100 non-cemented Triathlon CS total knee systems with different liners (N2Vac and X3). All patients had symptomatic knee osteoarthritis. Follow up (FU) was 2 year.

Table 1: PROMs and RSA follow up moments

FU moment	Clinical analysis	RSA Supine	RSA Standing
Direct post-op		1 RSA x-ray	
6 weeks	PROMs		1 RSA x-ray
3 months	PROMs	1 RSA x-ray	
6 months	PROMs	1 RSA x-ray	
1 year	PROMs	2 RSA x-ray s	1 RSA x-ray
2 year	PROMs	1 RSA x-ray	1 RSA x-ray

RESULTS AND DISCUSSION

Of 100 included patients 93 cases (3 withdrawals, 2 lost to FU, 1 met exclusion criteria, 1 surgery not within enrolment period) completed their 2-year follow up. Reported are 1 post-operative (PO) infection (no loss of components) and 1 revision of the tibial component (due to surgical error).

An intermediate analysis with regard to the primary objective shows no significant wear. These results are not surprising considering the early FU time. After an initial migration up to 3 months the RSA results showed that the majority of cases, for both femoral and tibial components, had no further migration in any direction (table 2). No significant differences between groups were found in the PROMs neither pre-operative nor PO. PO all patients increased in clinical functional outcome without significant differences between groups. At 6 weeks FU the SF-36 shows a decline at the Physical domain, social and emotional functional domains, which recovers at 3 months and further increases at longer FU. Earlier reported analysis of our group [4] showed the possibility of clinical importance of "inducible micro motion". Calculating the migration in between supine and standing RSA acquisitions at 1 year assessed this. The same analysis at 2-year FU showed similar "inducible displacement", but didn't show any significant correlation with the 1-year RSA analysis along all three orthogonal axes.

Table 2: 2 year translations of femur and tibia components

	Translation (mm) Femur			Translation (mm) Tibia		
FU moment	**X-axis**	**Y-axis**	**Z-axis**	**X-axis**	**Y-axis**	**Z-axis**
3 months (SD)	0.00 (0.22)	0.15 (0.17)	0.06 (0.38)	0.02 (0.22)	-0.11 (0.32)	-0.03 (0.30)
6 months (SD)	-0.01 (0.29)	0.18 (0.19)	0.11 (0.42)	0.01 (0.24)	-0.07 (0.33)	-0.05 (0.35)
12 months (SD)	-0.02 (0.28)	0.21 (0.21)	0.06 (0.43)	0.02 (0.28)	-0.04 (0.34)	-0.03 (0.41)
24 months (SD)	-0.04 (0.34)	0.21 (0.22)	0.08 (0.45)	0.02 (0.31)	0.00 (0.35)	-0.03 (0.44)

CONCLUSIONS

1. No differences of liner wear between standard and highly cross-linked UHMWP liners at 2-year FU.
2. Almost all components (both femoral and tibial) show an initial migration, followed by stabilisation at 3 months.
3. Peri-apatite coated non-cemented Triathlon CS components can be safely used in total knee arthroplasty.
4. No correlation between "Inducible micro motion" at 1 and 2-year FU. Further analysis must be done at 5 years.

ACKNOWLEDGEMENTS

The research is funded by Stryker Netherlands. The sponsor had no influence on data analyses

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Pelvic tilt between supine and standing after total hip replacement

106 patients examined with RSA up to 7 years after the operation

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INTRODUCTION

Orientation of the acetabular component in a total hip replacement (THR) plays an important role for stability and long-term clinical results [1, 2]. The pose of the prosthetic components after operation with THR is commonly evaluated on conventional radiographs. Any change of the pelvic position after the operation in the supine and between supine and standing position in the postoperative period will influence validity of the measurements. We evaluated the change of pelvic tilt angel (PTA) in the supine and standing position up to 7 years after operation. The aims of our study were (1) to evaluate if the PTA change over time in patients operated with a THR, (2) to assess any difference in the PTA between supine and standing positions, and (3) to investigate whether factors such as gender, the condition of the opposite hip or low back pain have any influence on PTA after THR.

METHODS

Repeated Radiostereophotogrammetric (RSA) radiographs of 106 patients (106 hips) were studied. All hips had been examined supine postoperatively and both supine and standing at 6 months and 7 years after the operation. Pelvic rotations about the transverse axis (anterior/posterior pelvic tilt) were analyzed.

RESULTS AND DISCUSSION

In supine the pelvis tended to show an increasing mean posterior tilt with increasing follow-up. From supine to standing the pelvis tilted in the opposite direction. At 6 months the mean anterior tilt was 3.6˚ (CI: 2.8˚ to 4.3˚) which increased to 6.4˚(CI: 5.7˚to 7.2˚) at 7 years (Table 1). Females showed larger posterior tilt in supine and more pronounced anterior tilt between supine and standing position during the entire follow-up. The condition of the opposite hip did not have any influence on the PTA when evaluating supine to standing at 7 years. From supine to standing, patients with low back pain displayed a weak and insignificant tendency towards larger anterior tilt at both occasions. No difference was found between the 2 groups in supine position.

Table 1: Anterior (+) / Posterior tilt (-) in the supine and standing positions in 106 patients up to 7 years after THR

	n	Mean (95% CI)	P value*
Supine			
Postop-6 months	106	-2.0˚(-2.6˚to -1.4˚)	
Postop-7 years	106	-2.7˚(-3.3˚to -2.2˚)	**0.010**
Supine to standing			
6 months	106	3.6˚(2.8˚to 4.3˚)	
7 years	106	6.4˚(5.7˚to 7 .2˚)	**<0.001**

Student´s t-test

CONCLUSIONS

Up to 7 years after insertion of a THR, the pelvis tilts slightly posteriorly in the supine position. When rising to standing the pelvis tilts in the opposite direction. This tilt increased with time and reached an average of about 7 degrees in females and 5 degrees in males. In individual cases this tilt might amount up to as much as 15-20 degrees. The results of our study revealed that pelvic tilt changed by varying degrees after THR. Particularly female patients displayed a larger PTA both in supine and standing positions. A large PTA after THA may cause dislocation and wear of articular surface. Hence, increased knowledge on postoperative changes of pelvic is of great significance to improve the outcomes of THR.

ACKNOWLEDGEMENTS

We thank Zimmer-Biomet and Link for supporting this project.

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1. The institution of the authors has received institutional support during the study period from Zimmer-Biomet and Link. One of the authors of this paper (JKÄ) is a board member of RSA Biomedical and has a financial relationship with the organization that could influence or bias the content of the paper.

THE EARLY MIGRATION OF POROUS TANTALUM ACETABULAR COMPONENTS USED AT REVISION THR: A COMPARISON OF RSA AND EBRA RESULTS

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INTRODUCTION

Aseptic loosening is the most common reason for re-revision of acetabular component used at revision total hip replacement (THR) [1]. Measuring early migration of acetabular components has been shown to be a good predictor of late aseptic loosening [2,3]. The amount migration at two years has subsequently been used to assess the likely long term performance of newly introduced acetabular component designs and treatment methods.

Two common radiographic measurement methods are Radiostereometric Analysis (RSA) and Ein-Bild-Roentgen-Analyse (EBRA). Nieuwenhuijse et al. [2] identified a threshold of >1.7mm proximal translation at two years postoperatively using RSA measurements as having 100% positive predictive value to predict late aseptic loosening at re-revision. Kim et al. [3] identified a threshold of >1mm on EBRA measurements as having 90% positive predictive value to predict component loosening status at re-revision.

The aim of this study was to measure the migration of porous acetabular components used at revision THR using both RSA and EBRA measurement methods.

METHODS

We performed a prospective cohort study of 33 patients undergoing revision THA at the Royal Adelaide Hospital between 2007 and 2014. All cases had large existing bone defects and were treated using a large uncemented acetabular component (Trabecular Metal, Zimmer, Warsaw IN). Tantalum beads were implanted at the time of operation to allow RSA. Plain anteroposterior (AP) pelvic radiographs and RSA exams were performed 4 days postoperatively and at 3, 6, 12, 24 and 36 months.

Measurement of proximal translation at two years was performed on plain AP radiographs using EBRA software and RSA radiographs were analysed using UmRSA software (v6.0, Umea, Sweden). Two year proximal migration derived using RSA and EBRA was compared to previously described thresholds.

RESULTS AND DISCUSSION

Twelve cases could not be included in the results due to the EBRA software excluding the AP radiograph due to excessive pelvic tilt. The median proximal migration as measured EBRA (0.3mm, IQR -0.2 to 0.6mm) was non-significantly higher than that measured by RSA (0.2mm, IQR 0.0 to 0.4mm); the median difference was 0.1mm, paired t-test (Wilcoxon matched pairs p=0.6). Only one component out of 24, as measured by RSA, was identified to be above the migration threshold of 1.7mm at 2 years as described by Nieuwenhuijse et al. [2]. The same component was above the migration threshold of 1.0mm at 2 years described by Kim et al. [2].

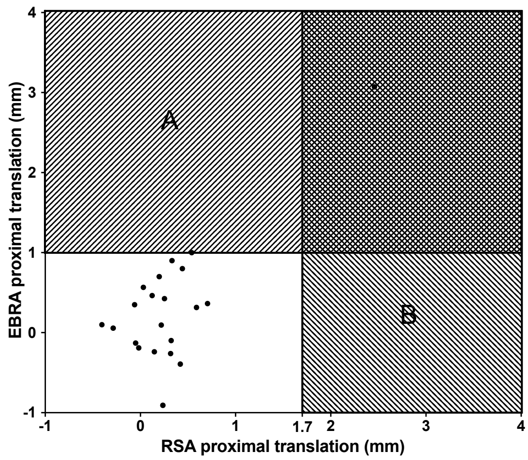

Figure 1: The proximal translation (mm) for each case at two years as measured by RSA (x axis) and EBRA (y axis). RSA identified 1 component migrating above the threshold reported by Nieuwenhuijse et al. (>1.7mm, Area B). EBRA identified the same case migrating above the threshold reported by Kim et al (>1.0mm, Area A).

CONCLUSIONS

RSA and EBRA measurements both identified a similar mean proximal migration for this cohort, although EBRA measurements were more variable and resulted in a relatively larger number of exclusions due to changes in pelvic tilt in AP pelvis radiographs. Good quality plain radiographs are required to allow EBRA analysis. Only one acetabular component was identified as at risk of late aseptic loosening using previously reported migration thresholds. Further investigation with a larger cohort is required to examine the ability of both EBRA and RSA to accurately identify individual patients at risk of later loosening.

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RADIOSTEREOMETRIC ANALYSIS OF INTERNAL DISC STRAINS DURING MORE PHYSIOLOGIAL SIMULATION OF REPETITIVE LIFTING MOTIONS

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INTRODUCTION

Repetitive manual handling is the most common mechanism for disc injury and disease among people aged 25-64 years [1], resulting in a direct and indirect health expenditure in Australia of over $3 billion [1]. Despite its high resilience, studies have shown intervertebral discs can be damaged during repetitive loading at physiological motions, causing cumulative damage [2]. Disc strains have been measured in-vitro during static six degree of freedom (6DOF) loads [3], however no studies have measured internal disc strains during repetitive complex loading (combination of compression and multiple modes of bending.)

The aim of this project was to examine associations between the magnitude of 3D internal strains, tissue damage and macroscopic evidence of disc herniation after repetitive lumbar motion in normal lumbar discs.

METHODS

Sixteen cadaver lumbar functional spinal units (FSUs) were subjected to pre-test MRI scans to identify normal discs (Pfirrmann grades II-III) [4], and to establish the initial disc tissue appearance. Eight FSUs (control group) underwent 20,000 cycles (or until failure) of loading under compression (2.5 MPa) + flexion (13°) + right axial rotation (2°) using a novel 6DOF Hexapod Robot [5]. These motion combinations were chosen because flexion and axial rotation have been clinically linked to herniation [6]. The remaining eight FSUs (experimental group) were tested under the same loading conditions, however, a grid of tantalum wires was inserted into the disc, and radiostereometric analysis (RSA) was used to calculate internal 3D displacements and maximum shear strain (MSS) [3]. Stereo-radiographs were taken at increasing intervals of repetitive lumbar motion (initial neutral position, 1, 500, 1000, 5000, 10000, 15000, 20000 cycles). Post-test MRI was conducted on all FSUs after testing. Discs were assessed via MRI and macroscopically examined to determine the extent of tissue damage and correlated with regions of highest internal disc tissue strains.

RESULTS AND DISCUSSION

This extensive study is currently underway and the preliminary results of six FSUs, three in each group, revealed substantial tissue disorganisation and disc injury after complex repetitive loading. Large increases in disc tissue displacements were observed in the anterior and posterior regions of the disc after 20,000 cycles. Similarly, the largest mean (95% CI) MSS of 58.14 (5.43) % after 20,000 cycles was found in the anterior region, with high MSS also seen in the right anterior lateral region (RAntLat, 50.55 (4.57) %) and left posterior lateral region (LPostLat, 51.34 (5.76) %). Pre and post-test MRI analysis revealed that five of six specimens presented with injury and apparent disorganisation in the nucleus (Figure 1). These injuries include endplate fracture (N=4), nucleus migration posteriorly (N=3), annular fissure (N=1), lateral and anterior annular tears (N=6).

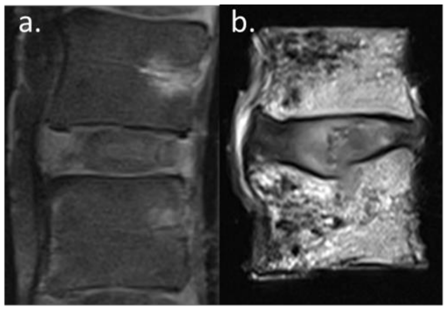

Figure 1: a. Pre-test MRI (T1) sagittal image of FSU. **b.** Post-test MRI (T1) sagittal image of the same FSU.

Macroscopic evidence of the FSUs revealed circumferential annular tears in the anterior region correlating with the high shear strains seen in that region. In addition, three FSUs showed evidence of nucleus extrusion in the LPostLat annular region, corresponding to the large shear strains there and indicating possible herniation.

CONCLUSIONS

Repetitive compression, flexion and axial rotation led to large shear strains in anterior and LPostLat regions that corresponded to annular tears in those regions in normal to mildly degenerated human discs. Future testing of the remaining specimen will help understand the mechanical loading conditions and mechanisms that lead to lumbar disc herniation. The manner, in which, an individual loads their spine is perhaps one of very few modifiable risk factors that can be addressed to prevent such injury occurring.

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STABILITY AND FUNCTION OF THE PRODISC-C VIVO CERVICAL DISC REPLACEMENT: FEASIBLE WITH RSA?

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INTRODUCTION

Cervical total disc replacement (CTDR) seems promising in patients with cervical diseases, but concerns as implant migration and spontaneous fusion are described [1]. The Prodisc-C Vivo is a new cervical intervertebral disc prosthesis that enables mobility. As this implant is implanted without additional fixation, it is important to investigate the stability with regard to the adjacent cervical vertebrae. Prior 'phantom' and feasibility-studies showed that the accuracy of model-based (MB) RSA is only acceptable for translation (<1mm; rotation was >1°).

Purpose: to evaluate the stability of the Prodisc-C Vivo in the intervertebral space and its clinical performance in terms of pain and functional ability in patients with single level C3-7 radiculopathy due to herniated disc, degenerative disc disease or spondylosis.

METHODS

A cohort study was performed, including 16 patients (9 women), aged 44 years (range 28-54), who met the selection criteria. Main inclusion criteria: adult, single level C3-C7 radiculopathy due to degeneration and preserved motion at symptomatic level. Main exclusion criteria: previous surgery at index level, disc height <50%, and comorbidities. RSA radiographs were obtained at the first post-operative day, at 6 weeks, and at 3, and 6 months follow up. Migration (translation in mm) of both components of the implant with regard to the adjacent cervical vertebrae was measured with MB-RSA (RSAcore, Leiden, the Netherlands). At 6 weeks, double RSA radiographs were obtained to assess the precision. Secondary, clinical results were described using the Neck Disability Index (NDI; 0-100), pain intensity (NRSneck and NRSarm; 0-10), satisfaction (NRSresult; 0-10), and adverse events (AE).

RESULTS AND DISCUSSION

We encountered several technical challenges. First, placing (enough) markers in vertebrae through a small surgical entrance was difficult. Due to the small size of the vertebrae, the marker models were also small in size, and this resulted in high condition numbers. (Figure 1) At the moment of abstract submission, not all CAD models for all sizes were available so no definitive results can be presented yet; the final results will be available at the time of the conference.

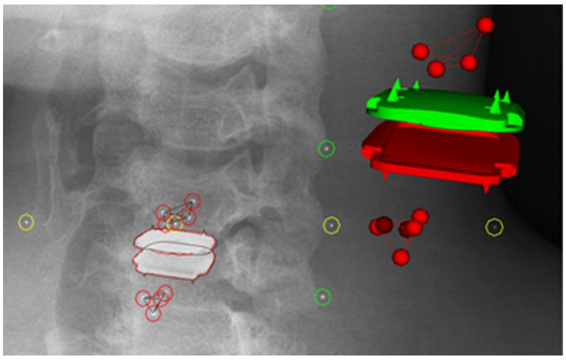

Figure 1: screenshot of model Prodisc-C Vivo and superior and inferior marker models in adjacent vertebrae.

Clinical results (baseline; 6m, median [range]) up and until 6m are available from 13/16 patients:
NDI (43 [14-82]; 12 [0-62]), NRSneck (6 [1-10]; 2 [0-7]), NRSarm (6 [1-9]; 1 [0-7]), and NRSresult (8 [0-10]; 10/13 are satisfied with symptoms neck at 6m. In total, 3 AEs in 3/16 patients occurred (1 persistent pain in neck and arm; 1 postoperative hoarse; 1 increasing headache).

CONCLUSIONS

Primary translational stability can be measured for both components of Prodisc-C Vivo cervical disc replacement in patients. Clinical improvement seems to be achieved. Final RSA study results will be presented at the time of the conference.

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CONFLICT OF INTEREST DECLARATION

In the interests of transparency and to help reviewers assess any potential bias, all authors of original research papers are required to declare any competing commercial interests in relation to the submitted work. Referees are also asked to indicate any potential conflict they might have reviewing a particular paper.

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   This investigator-initiated study is financially sponsored by AO Foundation (funding to research department).

DAY 1

POSTERS

High carbohydrate high fat diet induced metabolic overload cause osteoarthritis-like changes of the cartilage and shift macrophage polarisation status in a rat model

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INTRODUCTION

Osteoarthritis (OA) has been long described as a non-inflammatory disease; however, patients with OA have a variable degree of chronic synovial inflammation, and this histopathology is increasingly recognized as a common feature in at least one subtypes of OA [1]. Obesity has been attributed in a major risk factor for developing and accelerating disease progression in OA, however, the mechanisms underlying this link are unclear [2}.The purpose of this study was to investigate whether activated synovial macrophage are involved in cartilage degradation in experimental obesity, and if they are, to study how obesity induced modulation of macrophage polarization affects the development of OA pathology.

METHODS

Wistar rats were fed with high-carbohydrate–high-fat (HCHF) or corn starch (CS) diet from 10 to 26 weeks of age. Pathological changes in synovium and cartilage were compared between groups. Immunohistochemistry of obese and control rat knee joint sections were performed to demonstrate specific expression of activated macrophages. *In vitro,* rat primary chondrocytes and conditioned medium of activated macrophage (M1/M2) in co-culture were used as cellular model to investigate whether polarized macrophage play role in the detrimental effect on cartilage.

RESULTS AND DISCUSSION

Diet-induced obesity rat model leads to a significant accumulation of pro-inflammatory macrophages (M1) in the synovium of the knee joint. Along with synovial inflammation, OA-like cartilage changes were also observed. Furthermore, we demonstrated that synovial fluid of HCHF rats alters macrophage polarization and chondrocytes. In addition, M1 polarized macrophages significantly inhibit SOX9 and ACAN and induce MMP-13 and RUNX2 gene expression.

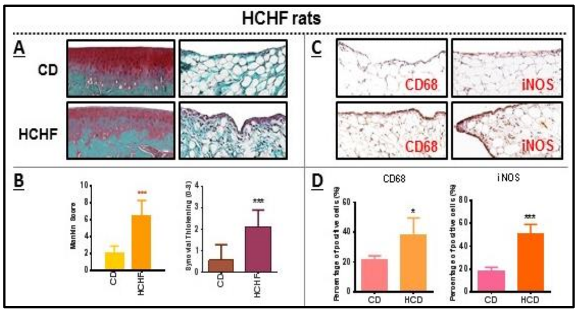

Figure 1: M1 macrophage negatively affects chondrogenic differentiation of ACCs. (A) Representative histological images of the knee cartilage and synovium in HCHF group. (B) Overall knee Mankin Scores and Overall synovitis Scores. (C) Immunohistological assay showing macrophages expression. (D) Percentage of total positive cells was used as a standard measure to quantify.

CONCLUSIONS

These results indicated that obesity affects the balance of M1/M2 macrophage and lead it skewing toward a pro-inflammatory state in synovium. M1 polarized macrophage elicit and unfavorable effect of chondrocytes by directly impacting chondrogenic expression.

ACKNOWLEDGEMENTS

The project is supported by the Prince Charles Hospital Foundation.

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USE OF ANODIC OXIDATION TO ENHANCE THE BIOCOMPATIBILITY OF TANTALUM IMPLANTS

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INTRODUCTION

Tantalum (Ta) is increasingly being used in orthopaedic applications owing to its superior non-toxicity, fracture toughness, and corrosion resistance in comparison to titanium [1]. The tantalum metal surface has an inherent oxide layer similar to what is observed in titanium and its alloys. However, the surface topology and chemistry of this layer are not conducive to integration to the bone; thus alteration is required to prevent joint failure [2]. The topology of the Ta-implant surface can be modified by anodisation in an acid electrolyte [3] to produce a porous and rough coating. Furthermore, the surface chemistry and resultant biological response of these coatings can be modified by incorporating specific ions on the surface. This can be either done through the selection of the appropriate electrolyte or by ion implantation on the coating surface. Moreover, the oxide layer formed (i.e., Ta_2O_5) is expected to have photocatalytic properties and it is possible to activate them to produce an anti-microbial effect using X-rays, as has been observed for TiO_2 coatings on Ti6Al4V implants [4]. The present work investigates the effects of the anodization parameters and post-anodisation treatment on the characteristics of the coatings formed by anodization, and their impact on osteoblast growth..

METHODS

Tantalum plates (99% purity, 0.5 mm thickness) were cut into substrates of 20 x 10 mm^2. Samples were anodized at current densities of 10-100 mA cm^{-2}, and voltages of 100-300 V. The anodization times were varied from 2 to 20 min. For the anodization at room temperature, Ti6Al4V alloy plates were used as the cathode, Ta metal as the anode, and 1 M H_2SO_4 as the electrolyte. Glancing angle X-ray diffraction (GAXRD) and laser Raman spectroscopy were used to determine the mineralogical characteristics of the coatings. Scanning electron microscopy (SEM) was used to analyse the surface morphology, particularly the pore distribution and pore sizes.
Cell culture studies using MG63 osteoblast cells were done to test the biocompatibility of the coatings.

RESULTS AND DISCUSSION

The anodization time, current density, and voltage had a significant effect on the characteristics of the coatings formed on the Ta metal surface. The mineralogical analysis data as seen from the Raman spectra showed that the Ta-oxide peaks observed were small and appeared to increase in intensity slightly with increase in the anodization voltage. The effect of increasing current density and anodization time were to increase the crystallinity of the coatings, although the effects were more prominent at the higher voltages. However, the coatings were still largely amorphous and thus heat treatment at higher temperatures (600°-700°C) is required to enhance the crystallinity and photocatalytic properties. In terms of microstructural development, low current densities and anodisation times did not cause any major alteration of the microstructures; however, at the highest voltages, current densities, and anodization times, the microstructure showed high numbers of micron- and nano-sized pores which were increasingly being distributed uniformly in the coating microstructure (Figure 1). The porous nature of the surface would enhance the roughness and provide an interlocking effect for improving the growth of osteoblasts on the surface.

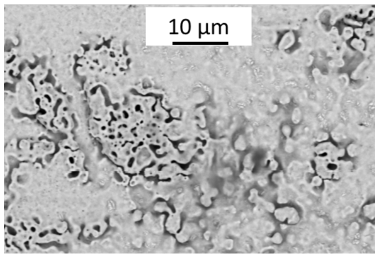

Figure 1: SEM image of the porous coating formed on the Ta metal surface by anodisation

CONCLUSIONS

Anodisation of the Ta surface was successful in fabricating an oxide coating that was porous and therefore supportive of the growth of osteoblasts. The surface characteristics can further be tailored by altering the anodization parameters. The surfaces formed by anodization can improve the biocompatibility and bonding of the implant surface to bone.

ACKNOWLEDGEMENTS

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BIOMECHANICS OF STAIR DESCENT IN PATIENTS WITH KNEE OSTEOARTHRITIS ENROLLED IN TKA

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INTRODUCTION

Osteoarthritis (OA) is a debilitating disease of the joint, currently affecting 2.1 million Australians [1], with this figure increasing. Symptoms of knee OA can include knee stiffness, crepitus and chronic knee pain, which lead to impaired activities of daily living. In instances where conservative treatment has not been successful, OA sufferers have no choice but to resort to total knee replacement (TKA) surgery.

Stair descent is described as the single most difficult daily activity for individuals suffering from knee osteoarthritis [2], and this is attributed to the large forces (up to four times body weight) experienced by the knee joint.

Understanding the gait characteristics of the OA joint is important as a predictive measure and way of determining early onset of OA. It is also important to be aware of which activity best identifies the early onset. We hypothesised that stair descent is a better measure of OA than walking when measuring joint kinematics.

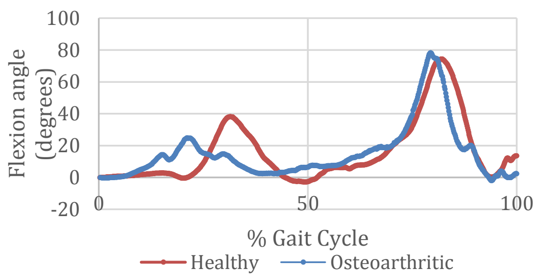
METHODS

Ten patients with severe osteoarthritis, who were enrolled for TKA surgery by a single surgeon were asked to participate in this study. Physical activity and pain levels were assessed using KOOS and WOMAC questionnaires. Ten healthy controls were also recruited for this study. The inclusion criteria for the healthy cohort consisted of i) aged between 45 and 75 years of age, ii) no pain in the lower limbs and joints and iii) no previous joint injury. Ethics approval for the study was obtained from Macquarie University and all participants provided informed consent.

Participants were marked with a modified Helen Hayes marker set. Twenty four reflective markers were placed on bony landmarks. Participants were first asked to walk barefoot along the walkway at a self-selected speed. They were then asked to descend down a 2 step staircase, with dimensions conforming to Australian standards. No hand rail was used during the experiment. Motion data was collected using an eight camera motion analysis system (Vicon, Oxford Metric Ltd, Oxford, UK). Two inbuilt force plates (AMTI, Newton, MA) were used during walking trials and a portal force plate was used on the first step of the stair descent trials. The 3D marker trajectory data was filtered using a Butterworth filter, cutoff of 6Hz. All subject gait data was averaged across the individual trials.

RESULTS AND DISCUSSION

The stair descent kinematic data better identified OA patients from healthy participants compared with the walking trials. Joint angles in all three planes showed distinct differences between the OA and healthy groups. The OA cohort showed considerable decrease in knee flexion angle and an increase in knee adduction angle compared with the healthy cohort during stair descent. Figure 1 shows a typical stair descent gait cycle of a healthy participant and of a patient with OA in the right knee. Peak angles between the two cohorts show patient with OA minimising the level of knee flexion, when the OA knee is fully weight-bearing. Patients also exhibited a faster pace when the OA knee was weight-bearing.



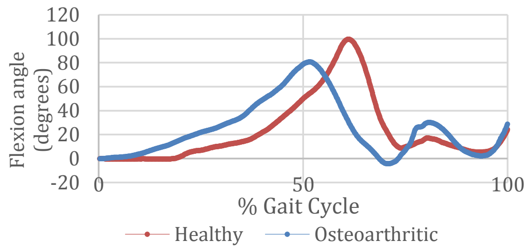


Figure 1: Typical graphs of Flexion angle during stair descent with participant stepping down from standstill with the left foot. Top image shows the flexion angle of the left knee and lower image shows the flexion angle of the right knee for the same trial. This participant had OA in right knee.

CONCLUSIONS

Stair descent activity is a better measure of identifying knee OA patients, compared with walking gait trials. Knees with OA exhibited less flexion and more adduction than healthy knees.

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ASSOCIATION BETWEEN BONE MICROSTRUCTURE, MICRODAMAGE, VASCULARITY AND BONE MARROW LESIONS IN THE SUBCHONDRAL BONE OF KNEE OSTEOARTHRITIS

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INTRODUCTION

It is currently hypothesized that structural changes of subchondral bone (SCB) play a pivotal role in both initiation and progression of osteoarthritis (OA). While in animal models of OA the sequences of SCB structural changes are well explained, in humans our understanding is less clear. Bone marrow lesions (BMLs) identified by magnetic resonance imaging (MRI) as a pathology of SCB are of considerable clinical interest because they correlate strongly with the severity of knee OA symptoms, structural degeneration, and are a strong predictor of total knee replacement (TKR). The factors underlying the development of BMLs and how BMLs are associated with specific bone structural alternation in the OA tibial plateau are unknown.
The aims of this study were to determine the association of the presence/absence of BMLs with type and degree of SCB structural changes, bone matrix microdamage, osteocyte/lacunar density and bone vascularity, in relation to the progression of knee OA.

METHODS

Tibial plateau (TP) were collected from 73 subjects aged 49 to 79 years undergoing TKR surgery for knee OA and from 12 non-OA control cadaveric subjects aged 44 to 89 years. MRI was used to identify BML presence and to quantify cartilage volume. Microstructure of the SCB plate and trabeculae was assessed by micro-CT imaging. Histoquantitative assessment of microdamage accumulation, bone resorption indices, osteocyte/lacunar density, and vascular features was performed for SCB plate and trabeculae.

RESULTS AND DISCUSSION

In OA subjects, we identified two different types of microstructural changes dependent on the presence or absence of BMLs. SCB without BMLs demonstrated evidence of bone loss [thinner subchondral plate (p=0.03), reduced number (p=0.04) and thinner trabeculae p=0.0001)] consistent with SCB structural changes previously described as an early stage of OA. The SCB containing BML was characterized by specific sclerotic changes [thicker plate (p=0.0005), higher bone volume (p=0.0001), an increased number of trabeculae (p=0.04) which were thicker (p=0.0001, less separated (p=0.04) and more plate-like (p=0.009) which together resemble changes characteristic of late stage of OA.

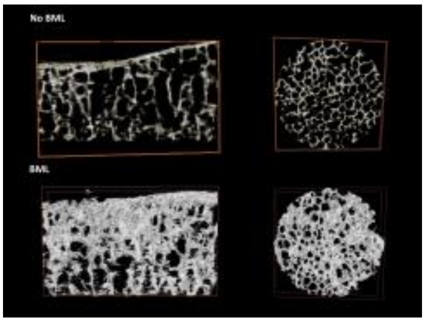

Figure 1: Micro-CT images of no-BML tissue and BML tissue.

Comparing BML tissue and No BML tissue, several key parameters were increased in BML tissue. These included increased microcrack burden (p=0.01, p=0.0001) in the SCB plate and trabeculae respectively, which associated positively with bone resorption (r=0.41, p=0.01 and r=0.34, p=0.04), and negatively with cartilage volume (r=-40, p=0.03 and r=-0.42, p=0.02), greater osteocyte numerical density (p=0.02, p=0.01) in the SCB plate and trabeculae, respectively and increased arteriolar density (p=0.004, p=0.0006) in the SCB plate and trabeculae respectively. The marrow tissue within BML zones contained and altered vascular characteristics, in particular increased arteriolar wall thickness (p=0.007) and wall:lumen ratio (wall thickness over internal lumen area) (p=0.001). Increased bone matrix microdamage and altered vasculature in the SCB of BMLs is consistent with overloading and vascular contributions to the formation of these lesions.

CONCLUSIONS

In conclusion, our data suggest that subchondral bone is intimately involved in the progression of OA. The accumulation of microdamage in BMLs supports the notion that excessive and biomechanically unfavorable loading contributes to the occurrence of BMLs in tibial subchondral bone tissue. Since these factors are modifiable, our findings suggest that early focus on reducing joint loading and using MRI-identifiable BMLs as an outcome measure may aid to the development of individualized OA treatment programs.

OSSEOINTEGRATED PROSTHETIC LIMB FOR THE RECONSTRUCTION OF LOWER LIMB AMPUTATIONS: OUTCOMES AT 1-YEAR FOLLOW-UP

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INTRODUCTION

Osseointegration is a dramatically different approach for the treatment of lower limb amputations, which involves direct attachment of the prosthesis to the residual bone. This approach can avoid the socket-interface issues associated with traditional socket prostheses. Osseointegration surgery is performed using two implant types. The first type is a screw-fixation implant, which only allows bone on-growth and raises concerns for long-term survival. The second type is a press-fit implant with a macroporous surface, which promotes bone in-growth. Osseointegration implants used in Australia are based on the second implant type, consisting of the Integral Leg Prosthesis (ILP; Orthodynamic GmbH; Lübeck, Germany) and the Osseointegrated Prosthetic Limb (OPL; Permedica s.p.a; Milan, Italy). The ILP has been in clinical use for over 15 years, and its outcomes in the reconstruction of limb amputations have been recently reported [1]. The OPL was developed in 2013 with improved materials selection and implant design to optimise reconstructive outcomes (Figure 1). The objectives of this study are to report, for the first time, the Australian experience with the OPL and present the clinical findings so far on its safety and efficacy, including quality of life and functional outcomes and the prevalence of adverse events.

Figure 1: The OPL implant system for the osseointegrated reconstruction of lower limb amputations.

METHODS

This is a retrospective study of 22 patients with unilateral trans-femoral amputation, who experienced socket-related problems and subsequently received the OPL implant during 2013–2014 in Sydney, Australia. Osseointegration surgery, post-operative care and rehabilitation were conducted according to published protocols [2]. Clinical outcomes were obtained pre- and post-operatively, with results reported at 1-year follow-up. Outcome measures included the Questionnaire for persons with a Trans-Femoral Amputation (Q-TFA), Short Form Health Survey 36 (SF-36), Six Minute Walk Test (6MWT), and Timed Up and Go (TUG). Adverse events were monitored and recorded. This study has been approved by the human research ethics committee and all participants provided their informed consent.

RESULTS AND DISCUSSION

All patients were walking and using the osseointegrated prosthesis at the 1-year post-operative follow-up. Compared to the mean pre-operative values obtained while patients were using socket prostheses or were wheelchair-bound, the mean post-operative values obtained 1 year after osseointegrated reconstruction using the OPL implant were substantially improved for all four validated outcome measures (Figure 2). Severe adverse events following osseointegrated reconstruction using the OPL implant were rare. A total of 15 episodes of minor infections occurred in 12 patients, all of which responded to antibiotics. Soft tissue refashioning was performed electively on 6 patients. No other adverse events were recorded.

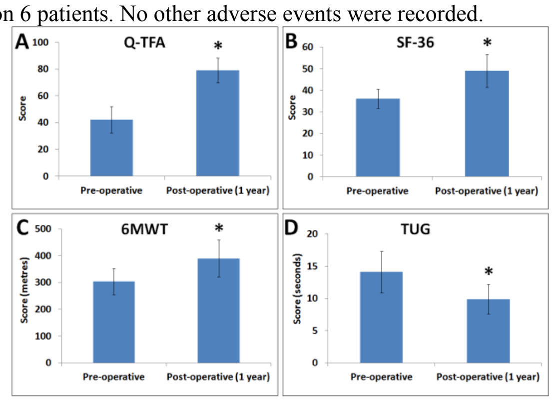

Figure 2: Improvements in pre- to post-operative values at 1-year follow-up for osseointegrated reconstruction using the OPL implant, including quality of life measures (Q-TFA, SF-36) and functional measures (6MWT, TUG). *$p < 0.05$.

CONCLUSIONS

The OPL implant features a unique design that can maximise the benefits of osseointegration surgery by providing significant gains in quality of life and function, while maintaining low levels of adverse events. This implant has potential to be widely utilised as an improved osseointegration system for the reconstruction of amputated limbs.

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EPIGENETIC REGULATION OF HUMAN OSTEOBLASTS BY INHIBITION OF HISTONE DEACETYLASE 5 ENHANCES MARKERS OF BONE FORMATION *IN VITRO*

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INTRODUCTION

Up until the year 2000 the word epigenetics hardly appeared in the scientific literature. Since then there has been surge in interest in epigenetics and in the use of the term in mainstream scientific publications. Epigenetics is a way of regulating gene expression without altering base pair sequencing through the traditional molecular means. In this study it is through the acetylation and de-acetylation of histone proteins that allows access to transcription of selective sequences of DNA. This offers a powerful way of regulating the way cells mature. Initially a number of histone deacetylase enzyme inhibitors (HDACi) have been used successfully to treat cancer. Recently more specific HDACi have been developed and these compounds have been shown to regulate a variety of cells at concentrations much lower (10-100 fold) than that of their chemotherapeutic effects. Our recent publications have demonstrated that HDACi that target specific HDAC enzymes can have a profound effects on osteoclastic formation and bone resorptive activity *in vitro* and *in vivo*. In diseases such as periodontitis, rheumatoid arthritis, and peri-prosthetic osteolysis an imbalance between bone resorption and bone formation occurs, possibly through the effects of inflammatory cytokines such as tumour necrosis factor-α (TNFα). Based on our preliminary studies of HDAC expression in these bone pathologies we aimed to target the expressed HDAC 5 isoform to investigate its role during the anabolic processes of bone formation.

METHODS

Human osteoblasts cells isolated from bone chips from healthy donors (n=8). The osteoblasts were cultured over a 21day period in the presence and absence of the inflammatory cytokine TNFα (10ng/ml), with targeted HDACi therapy (Compound 39; 0.1-1000nM).

RESULTS AND DISCUSSION

We found that the inhibition of the HDAC 5 enzyme (20nM) significantly enhanced *RUNX2* expression ($p<0.05$), a key transcriptive factor for osteoblastic maturation and activity. Similar increases were seen in other markers of maturation and bone formation, *OCN, OPN*, and *COL1A1*. HDAC5 inhibition induced substantial increases in mineralized deposits and alkaline phosphatase activity ($p<0.05$) in human osteoblasts. Similar results were observed in the presence and absence of TNFα that was used to mimic an inflammatory state.

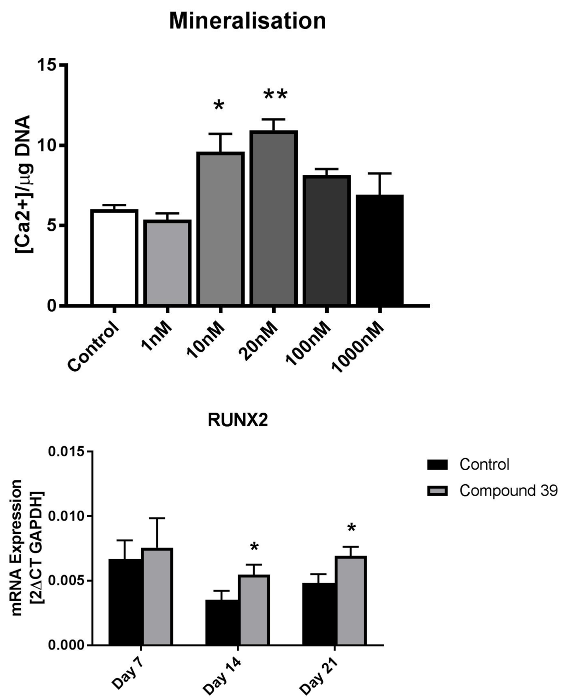

Figure 1: Mineralisation at day 21 (top) and RUNX2 expression during culture (bottom).

CONCLUSIONS

Overall our findings show that HDAC 5 has an important role during osteoblast maturation and reductions in its expression or activity may be involved in promoting the anabolic processes of bone metabolism. This study supports the continued research into HDACi therapy as a potential option for osteolytic pathologies.

ACKNOWLEDGEMENTS

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ANTI-MICROBIAL BIOCERAMIC COATINGS ON Ti6Al4V SURFACES BY ANODISATION

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INTRODUCTION

Titanium and its alloys are a popular choice for biomedical implants, particularly knee and hip replacements, owing to their high biocompatibility and superior mechanical properties. The insertion of these implants is done through surgery and the resulting incisions provide an entry point for microbes, thereby increasing the risk of infections and rejection responses. These infections are difficult to treat and impact severely on patient health and implant lifetime. A potential solution is the fabrication of anti-microbial coatings of TiO_2 on the implant surface which are photocatalytic and can be activated by X-rays to provide an anti-microbial effect.

METHODS

Ti6Al4V alloy plates (10 mm x 40 mm) were anodised in an electrolyte mixture of 1 M sulphuric and 1 M nitric acids. Anodisation was done at a constant voltage (100 V) and current density (300 mA/cm^2). The relative proportions of the acids and the anodisation time were varied. Glancing angle X-ray diffraction (GAXRD) analysis was used to determine the mineralogy of the coatings, while scanning electron microscopy (SEM) was used to analyse the microstructural features. The photocatalytic characteristics of the coatings were assessed in terms of dye degradation tests under UV and X-ray irradiation. Cell culture tests were conducted to assess the growth and proliferation of osteoblasts on these surfaces. Anti-microbial tests were conducted by irradiation of the coatings after culturing *S. Aereus* on the coating surfaces.

RESULTS AND DISCUSSION

GAXRD analysis showed that the coatings contained different photocatalytic polymorphs of TiO_2, namely anatase and rutile. Varying the relative concentrations of the acids in the electrolyte assisted in varying the amounts of these phases. Of the two phases, anatase is preferred owing to its superior photocatalytic activity [1]. The anatase peak intensity was greatest when anodization was done for 5 min in an electrolyte with 20 vol% nitric acid. The peak intensity of rutile appears to have remained quite similar for all processing conditions. Upon irradiation with X-rays, the photocatalytic coatings would produce charge carriers that react with O_2 and H_2O, to form reactive oxygen species that can destroy microbes [3]. The anodization process resulted in the formation of a rough and porous microstructure with an even pore size distribution. (Figure 1). With increasing nitric acid in the electrolyte, the pore sizes appeared to become less uniform, particularly at shorter anodisation times. The porous microstructure and surface asperities can allow for enhanced growth of osteoblasts [2]. The rough surfaces provide an interlocking mechanism that can enhance osseointegration and the overall anchoring of the implant in the bone.

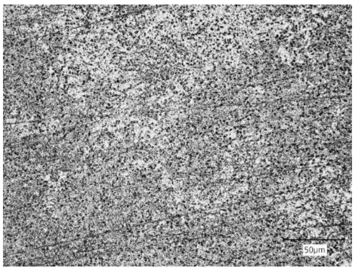

Figure 1: Porous and rough coating surface produced by anodization (20 vol% nitric acid + 80 vol% sulphuric acid),

CONCLUSIONS

The work identified the optimal anodization parameters for the fabrication of a photocatalytic TiO_2 coating on Ti6Al4V implant surfaces using an electrolyte mixture of nitric and sulfuric acid. The presence of anatase would enhance their anti-microbial characteristics, while the porous and rough coating surfaces would enhance cell growth and improve the anchoring of implants to bone tissue after implantation.

ACKNOWLEDGEMENTS

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Clinical RSA Research Network

Novel Antimicrobial Coating for Anti-infective Medical Devices

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INTRODUCTION

The use of any implanted foreign body in surgery has been shown to reduce the minimal infecting dose of S. aureus up to 1000 fold for formation of a permanent abscess[1]. In fact, implants are recognized as a major contributing factor to these infections because of the formation of bacterial biofilms, a self-secreted polysaccharide matrix which adhere to implant surfaces and protect the embeded bacteria from the immune system and systemically administered antibiotics[2]. The two commensal bacteria normally found on patient's skin Staphylococcus aureus (S. aureus) and Staphylococcus epidermidis (S.epidermis) have been identified as key bacteria in many of these infections [3]. The economic cost of surgical site infection in the US has been estimated by the Centre of Disease Control (CDC) at 3-10 billion dollars per year4. Orthopaedics is the surgical discipline that is strongly affected with implant infection which has average rate of approximately 1.2% for total hip replacement and 0.8% for total knee replacement1. It is estimated that additional USD 30,000 incurr in cost for treating such complication which is also correlated with up to seven fold increase in death risk 1.

In this study, new antimicrobial coating is developed to address the above clinical challenge. The coating takes advantages of the antimicrobial properties of nanoparticles and natural agents to achieve desired activity. Here we report the development of this coating technology.

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Influence of Surgical Variation in Stem Sizing and Positioning on the Primary Stability of Cementless Femoral Stems

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INTRODUCTION

Primary stability is essential for the success of a cementlesss total hip replacement (THR) [1]. Surgical variation in sizing and positioning may influence the short- and long-term success of the THR [2], however, the impact of such variation remains unclear. Understanding the influence of surgical variation requires the study of a wide range of possible scenarios, which is impractical solely using in-vitro methods. Using finite element (FE) modelling, possibilities of stem positions and sizes can be studied as part of implant performance evaluation. Hence, the aim of this study is to investigate the effect of surgical variation in sizing and positioning on the primary stability of a femoral stem using FE simulations.

METHODS

The computed-tomography (CT) images of the left femur from a male donor with no reported musculoskeletal disease (Age: 55 years, body mass: 94 kg, stature: 1.77 m) were taken from the Melbourne Femur Collection. The intact femoral geometry was segmented from the CT images using ScanIP (Simplewere, Exeter, UK). The femur was implanted with a standard offset Corail® stem (DePuy Synthes, Warsaw, USA) using a custom Matlab (The Mathworks, USA) script that automates the following: (i) selects the appropriate implant size and position (***nominal stem size and position)*** that restores the vertical offset of the femoral head centre, within ± 1 cm, maintains the alignment between stem and femoral axes and ensures maximum fill of the medullary canal, (ii) resects and prepares the cavity for the implant, then meshes the implanted geometry using Hypermesh (Altair Engineering, Troy, MI) ,(iii) assigns element-by-element linear-elastic isotropic material properties from CT data and (iv) applies loads and boundary conditions.

Size-related variations were introduced by reproducing the implanted model, however, with stems one size greater, one size smaller and two sizes smaller than the nominal size. For each stem size, position-related variations were introduced within the space prone to surgical variation. This space was defined by the cancellous bone thickness between the stem (in nominal position of each size) and the inner boundary of the cortical bone. Latin Hypercube sampling was used to automatically generate models for a total of 800 surgical scenarios (200 models per stem size), each with a unique stem size and position combination, using the custom Matlab script.

The peak joint contact and muscle forces during gait [3] were scaled to the subject's body mass and applied to the model. Distal nodes at the femoral condyles were rigidly fixed. Simulations were run using the implicit solver in Abaqus (Dassault Systèmes, France). Distributions of implant micromotion, peri-prosthetic bone strain and strain energy density were recorded. The risk of short- and long-term loosening of the implant was assessed as follows [4]: (i) the short-term risk of fibrotic tissue differentiation at the bone-implant interface (micomotion) and peri-prosthetic bone damage (interface strains), (ii) the long-term risk of adverse bone resorption using bone adaptation theory (% change in strain energy density/unit volume, relative to the intact femur).

RESULTS AND DISCUSSION

the condition for short-term implant loosening was never met (Figure 1). For the nominal position, changes in size resulted in slight variation in micromotion (range < 6 μm) and interfacial strains (range < 650 με). Changes in position resulted in more notable differences in the micromotion experienced by the stem (range > 45 μm) as well as the load distribution at the bone-stem interface (range > 4,500 με). The percentage of the peri-prosthetic bone exposed to low remodeling stimuli ranged from 20% to 38% of the contact area.

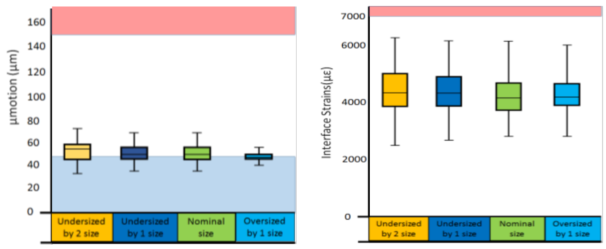

Figure 1: 90th percentile micromotion (right) and interfacial strain (left) profiles under level gait loads for the 200 stem positions for: (i) undersized stem by two sizes (yellow boxes) and (ii) undersized stem by one size (dark blue boxes), (iii) nominal size (green boxes) and the oversized stem (light blue boxes). The red region indicates thresholds that may lead to implant loosening, which is undesirable for THA.

CONCLUSIONS

Based on a single subject, the study demonstrated that, compared to the nominal position, variation in stem positioning is likely to result in relatively large variation in micromotion and strains. The study also suggests that mal-positioning may have a greater impact compared to error in sizing.

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FEMORAL FRACTURE DURING SIDE FALL: SENSITIVITY OF DYNAMIC FINITE-ELEMENT MODELS

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INTRODUCTION

A fall to the side is the main cause for hip fragility fracture in older adults, which in turn causes the highest mortality and morbidity rates among fragility fractures. Dynamic finite-element models based on computer-tomography (CT) can be used for the calculation of the risk of fracture in specific patients by integrating personalized information of anatomy, bone quality and fall dynamics [1][2] potentially leading to advanced diagnostic methods and personalized techniques for therapy assessment. However, validation studies, typically conducted by comparing femoral strains in the model with corresponding experimental measurements from in vitro drop-tower tests, report variable results (R < 0.35-0.63) making it difficult to understand the validity of current dynamic modelling techniques. The aim of the present study was to investigate the model sensitivity to the main variables of an *in vitro* experiment. This information will help developing enhanced validation studies of dynamic models of hip fracture.

METHODS

CT data (scanner: Optima CT660, General Electric Medical Systems Co.) of a human proximal femur (female, 79 y.o.) were segmented (Simpleware ScanIP) and converted to a NURBS based solid (GeoMagic Wrap, 3D Systems). The 3D geometry of the femur was meshed using 110,000+ linear tetrahedrons. The heterogeneous, locally isotropic, linear elastic material properties were extracted from the CT grey levels following an established procedure [1]. The strain-rate dependence was retrieved from [1]. The femur (oriented with 10° adduction of the shaft and 15° internal rotation of the neck [3]) was distally constrained by PMMA into a rigid pot free to tilt in the quasi-coronal plane, while the femoral head lied on an infinitely rigid cup free to translate in the horizontal ground plane (Fig. 1). A 2D infinitely rigid plate was used to simulate the dropped mass (impactor) according to a previous experimental setup [1]. The simulation of the drop-tower test was repeated by changing a set of parameters: a) the velocity of the impactor between 2.59 m/s and 3.17 m/s [1], b) the cup-to-ground friction coefficient between 0.04 (Teflon-on-polished stainless steel) and 0.16 (steel-oil-steel), c) bone-to-cup friction coefficient, d) mass of the impactor and e) mass of the cup. The range of each variable was taken from previous studies [1][2][3]. The FE analysis was performed using the explicit solver implemented in Abaqus (Dassault Systèmes). The bone-to-cup impact force was used as the metric for comparison. Preliminary simulations examined the sensitivity of the bone-to-cup force to impact velocity and cup-to-plate friction. A preliminary simulation was carried out to determine the time length of the impact event.

RESULTS AND DISCUSSION

The impact event was considered completed after 15 ms (Fig. 1). The peak of the bone-to-cup impact force showed a 8% variation due to changes of the impact velocity (4.31 kN vs. 4.00 kN) while negligible changes (< 1%) were found due to variations of the cup-to-ground friction coefficient.

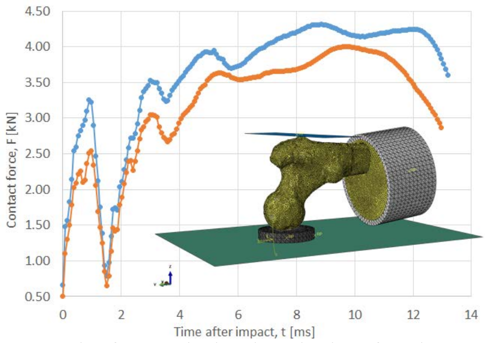

Figure 1: The force calculated at the interface between the femoral head and the sliding cup obtained by varying the impactor velocity between 2.59 m/s (solid orange) and 3.17 m/s (solid blue).

CONCLUSIONS

The preliminary results demonstrated i) the feasibility of the sensitivity analysis and ii) the sensitivity of the contact force on the femoral head's surface to changes of impact velocity, but not to variations of the cup-to-ground friction coefficient. Completing the study through analyzing the effect of all the aforementioned parameters will allow gathering important information on how to optimize the validation studies of the FE impact models for the drop-tower tests.

ACKNOWLEDGEMENTS

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UNDERSTANDING THREE-DIMENSIONAL FRACTURE PATTERNS OF THE TIBIA AND FEMUR IN ORTHOPAEDIC TRAUMA: ESTIMATING LONGITUDINAL AND CONDYLAR AXES BASED ON CT RECONSTRUCTIONS OF PARTIAL LENGTHS AND WIDTHS OF BONE

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INTRODUCTION

Fracture classification systems used for tibial plateau [1, 2] are based on x-ray imaging, therefore two-dimensional by nature. 3D imaging now gives an opportunity to deepen our understanding of fractures by considering their 3D nature. One of the first steps towards this is establishing a repeatable method for defining local coordinate systems to quantify and compare fracture patterns. The aim of this study was therefore to develop a method for systematically determining the anatomical axes of the tibia and femur from partial 3D imaging. Sensitivity of the method to change in the parameters used was assessed.

METHODS

CT scans of the full tibia were obtained from ten healthy adults. Additionally, CT scans of the knee were obtained from ten tibial plateau fracture patients. All scans were manually reconstructed using ScanIP (Simpleware, Exeter, UK). Data were imported into Matlab (R2016a, The Mathworks Inc., Natick, USA) for image processing and analysis. Using the full tibial scans, a cone was fitted to a set portion of the tibial shaft in the least-squares sense to establish the longitudinal axis of the tibia. The process was conducted for varying lengths of shaft, measured down from just below the tibial plateau, to determine the minimum length of shaft needed for a valid axis estimation. The full shaft was taken as a reference and a variance calculated from this compared to the partial lengths of shaft. A similar method was applied to obtain the femur mediolateral axis from a cone fitted to the posterior portion of the condyles. The width of the part of the condyles used for the fit was varied.

RESULTS AND DISCUSSION

Variation of the estimated tibial long axis with varying available shaft lengths is presented on Figure 1. Overall, the estimates were very close to the reference even with as little as 10mm available shaft length. For the femur mediolateral axis, the mean variance in the coronal plane angle was less than 1° for condylar widths between 5-20mm (Table 1). The axial angle had a mean variance within 3° across the varying condylar widths (Table 1). The estimated axes still need to be compared to a visual identification of the epicondyles by skilled operators which will serve as the reference.

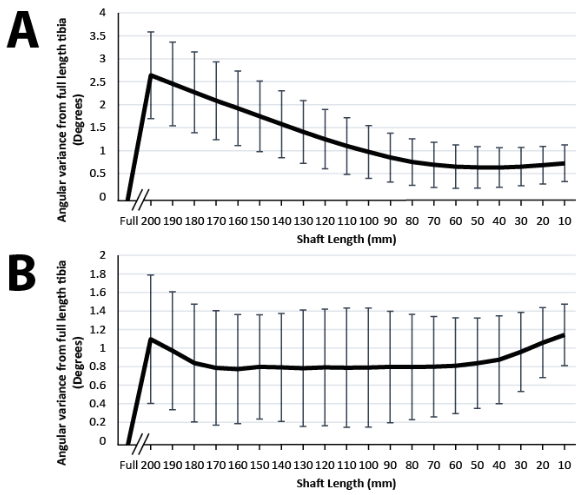

Figure 1. Mean variance of the longitudinal axis angles within the coronal and sagittal planes from the angle measured using the entire tibia. **A** – Coronal plane. **B** – Sagittal plane.

CONCLUSIONS

We have presented a valid method for systematically obtaining anatomical axes of the femur and tibia from partial CT imaging. This will serve as the foundation to 3D quantification of tibial plateau fracture patterns.

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Table 1: Axis angle variance across varying condylar widths.

	Condylar Width (mm)			
Planar Angle	**20**	**15**	**10**	**5**
Coronal (deg)	0.51 ± 0.27	0.63 ± 0.47	0.67 ± 0.35	0.47 ± 0.32
Axial (deg)	1.39 ± 0.61	2.00 ± 1.08	2.15 ± 1.41	2.72 ± 1.36

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THE EFFECTS OF ADVANCED GLYCATION END PRODCUTS ON THE NANO-STRUCTURAL PROPERTIES OF BOVINE CORTICAL BONE

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INTRODUCTION

An increase in non-enzymatic glycation of the collagen matrix in bone tissue can occur with aging and diabetes mellitus, and has implications for the risk of bone fracture. However, the mechanism of this change is not currently understood. The purpose of this study was to investigate the effect advanced glycation end products (AGEs) have on the nano-structural properties of bone tissue.

METHODS

Twelve samples of cortical bone from a bovine femur were divided into three groups – non-incubation control, incubation control and a treatment group. The incubation control and treatment groups were incubated in phosphate buffered saline (the treatment group had 0.6M D-Ribose added). The groups were then subjected to nanoindentation testing using the IBIS system.

RESULTS AND DISCUSSION

Nanoindentation testing showed a statistically significant increase in the hardness and elastic modulus in the treatment group compared to the incubated control group (hardness 0.0296 GPa ± 0.033 GPa [mean ± SD] for control and 0.0718 GPa ± 0.062 GPa for treatment; elastic modulus 0.430 GPa ± 0.50 GPa for control and 1.05 ± 0.95 GPa for treatment). These results show that the formation of AGEs in bone (in-vitro) resulted in increased local hardness and elastic modulus.

CONCLUSIONS

This suggests the need for further studies in human and in-vivo specimens to elucidate the applicability of these results to living human bone.

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	Treatment	**Incubation control**	**Non-incubation control**
Hardness (GPa)	**0.07178** (0.05062 - 0.09293)	**0.02964** (0.01728 - 0.04201)	**0.1788** (0.1419 - 0.2157)
Elastic modulus (GPa)	**1.045** (0.7221 - 1.369)	**0.4305** (0.2444 - 0.6165)	**2.598** (2.075 - 3.122)

OPEN SOURCE COMPARISON OF REGRESSION-BASED BODY SEGMENT PARAMETER MODELS

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INTRODUCTION

Body segment parameters, including mass, centroid, and moment of inertia, are used for biomechanical analyses and simulations. Errors in segment parameter estimates can propagate to calculations of muscle forces and joint loads [1]. Body segments were estimated originally with data from cadaver studies dating as early as 1860. Later cadaver studies in the 1950s-1970s improved upon these methods but subject numbers and population variation remained limited. Nonetheless the data from such studies remain commonly used.

More recently, various scanning methods (CT, MR, optical) have been used in more comprehensive studies to improve body segment parameter estimates for specific subject populations. Despite a wide range of data sets, no common repository of body segment parameter models has been collated. This study presents work to develop a comprehensive database of extant studies in this area. In the current work, the studies using regression variables of mass and height are compared, demonstrating significant variation and highlighting the need to chose body segment parameter models wisely.

METHODS

Tables of regression data for over 15 body segment parameter models were collated. For the results shown herein, the works of Zatsiorski [2] and Shan and Bohn [3] are highlighted since they both use mass and height as regression variables. The two works describe six models: Chinese, German, and Russian; male and female of each. In total, these models consist of 1500 regression coefficients. The coefficients were independently transcribed and compared to ensure correctness. Custom Matlab code was written to load the regression coefficients and provide an interface to easily calculate body segment parameters for each model. Tables of raw data and Matlab code are available at: http://wspr.io/body-segment-param

RESULTS

To demonstrate the utility of these models, three subjects of equal mass and varying height were used to calculate body segment parameter models. For each segment, a mean mass was calculated across all models (Table 1), and each segment mass in each model was compared relative to this mean (Figure 1).

Table 1: Mean masses (kg) of each segment for every model.

Head	*Thorax*	*Abdo*	*Pelvis*	*Arm*
5.2	13.1	9.4	8.3	1.7
Forearm	*Hand*	*Thigh*	*Shank*	*Foot*
1.0	0.4	9.6	3.2	0.5

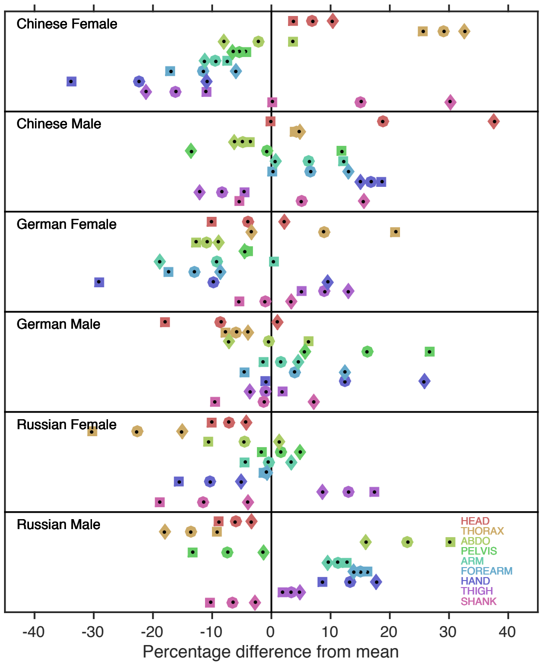

Figure 1: Example comparison between six BSP models comparing segment mass for individuals of weight 70 kg and heights 1.6m (square), 1.7m (circle), and 1.8m (diamond).

DISCUSSION

Data for the foot segment was omitted from the displayed results as their mass variations greatly exceed those of the other segments. It appears unlikely that the Chinese Male head mass should vary to such a large extent with small changes in subject height, warranting further evaluation. Results from the Russian Female model display abnormalities (e.g., consistently lower-than-mean mass) and additional investigation of Zatsiorski's works should be conducted to establish whether that regression model is valid or if his published tables of data are inconsistent.

We hope that the broader availability of such data sets promotes greater investigation and discussion of body segment parameter models.

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Ovariectomy induced ultrastructure and mechanical property changes in rat's maxillary bone

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INTRODUCTION
Ovariectomy (OVX) could cause estrogen deficiency which leads to bone loss and induce osteoporosis in female rats. Bone reacted to estrogen deficiency varies with positions owing to obvious differences of the embryological origin and the ossification process between jaw and long bones[1, 2], as significant decrease in bone mass was observed in long bones such as femur, tibia and vertebrae after OVX operation[3], however, it remains unclear whether OVX affects the ultrastructure and the mechanical properties of the maxilla alveolar bone during the bone remodeling and regeneration process. The aim of this study was to investigate the bone quality of maxilla in ovariectomized rats in both newly formed bone and the mature bone areas, using advanced analytical facilities such as scanning electron microscope with energy dispersive spectrometry (SEM/EDS), transmission electron microscope (TEM) and nanoindentation.

METHODS
Twelve Sprague Dawley 3- month old female rats were randomly divided into two groups. Six rats had a bilaterally OVX operation and other 6 rats underwent a sham operation (SHAM). The OVX operation as well as the sample collection procedures and the sample preparation for histology, SEM/EDS, TEM and nanoindentation were described in detail in our published studies related to dental implant-osteoporosis projects [4].
Statistical analysis was performed using one-way ANOVA with Tukey's HSD test. A difference was considered significant when $p<0.05$.

RESULTS AND DISCUSSION
The results showed the mature bone areas in the OVX group were significantly affected in both the mineral crystalline and the microstructure by the estrogen deficiency. The micro-mechanical properties of the mature bone was also affected, showing a significantly increased hardness *(H)* and reduced modulus (*Er*) in OVX rats in comparison with the normal rats, while the differences in *H* and *Er* in new bone areas between the normal and OVX rats were less significant. (Figure 1)

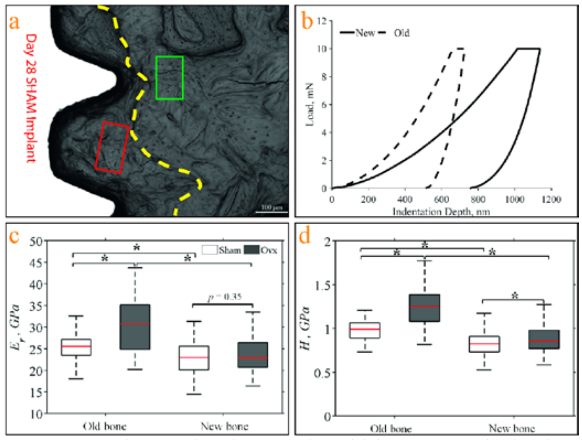

Figure 1: The results showed the old bone areas had a less penetration depth than new bone under the same maximum load, the OVX old bone areas with highest *Er* and hardness between groups. While the differences of new bone areas were not obvious compared with old bone results. (Fig 1a, Yellow dotted line separated the old bone and new bone areas. Green box and red box showed the indenting positons separately).

CONCLUSIONS
OVX affected the maxilla bone quality, however, the effects mainly existed in the mature bone areas, which was characterized with higher crystalline mineralization, hardness and modulus.

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DAY 3

<u>POSTERS</u>

SERUM METAL LEVELS AFTER REMOVAL OF SPINAL INSTRUMENTATION

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INTRODUCTION

With an increase in the use of spinal instrumentation, growing concern exists on the gradual degradation of prosthetic instrumentation with subsequent increase in serum metal levels. Spinal surgery using titanium alloy and chromium instrumentation has become common procedure in the treatment of degenerative conditions. Removal of spinal instrumentation is not routinely carried out due to conflicting evidence on its clinical benefits and is performed when late operative site pain, implant site infection, neurological implications, and implant failure are present. However, long term implantation may lead to corrosion and wear, leading to mechanical failure of the implant and release of metal ions yielding deleterious biological effects [1].

Retrospective research has shown elevated metal ion levels after instrumented spinal arthrodesis, however, no studies to our knowledge have investigated serum metal levels after removal of spinal instrumentation, prospectively. Therefore, the primary aim of this study is to measure and compare serum metal levels over time after removal of spinal instrumentation.

METHODS

This longitudinal cohort study measured serum titanium, chromium, and aluminium levels in 20 patients undergoing removal of spinal instrumentation due to late operative site pain, infection, or implant failure compared to baseline serum metal ion concentration levels of 20 patients undergoing surgery without spinal instrumentation. Serum samples were obtained pre-operatively and post-operatively for both the control and experimental groups and more serum samples were taken from the experimental group at 2 weeks, 3 months, and 1 year to measure the pattern of metal ion release. Samples were analysed using high resolution inductively coupled plasma mass spectrometry to measure titanium (Ti), chromium (Cr), nickel (Ni) and aluminium (Al) concentrations. Paired t-tests were used to compare serum levels between control and experimental groups. Repeated measures ANOVA was performed on metal serum levels (Al, Cr, Ti, and Ni) at four time points for the experimental group.

RESULTS AND DISCUSSION

Preliminary results indicate serum titanium levels were significantly higher in patients who underwent removal of metal surgery (mean, 2.27 µg/l) when compared with controls (mean, 1.01 µg/l, $p=0.003$). Patients within each group were matched for age and past exposure to metal implants. Serum aluminium ($p=0.563$), nickel ($p=0.217$) and chromium levels ($p=0.221$) were not statistically different between the two groups. Serum aluminium levels were statistically different between the four time points ($p=0.005$) for subjects undergoing removal of metal surgery, however, titanium, nickel and chromium levels were not significant ($p>0.528$). Serum metal ion levels trended to increase one day post-surgery and decrease at the time point of 2 weeks and 3 months to levels similar to before surgery. Significant increases in aluminium levels were seen after one day post-surgery in comparison to before surgery ($p=0.006$, Figure 1). In addition, significant decrease in aluminium levels were seen after 2 weeks in comparison to 1 day post-surgery ($p=0.049$). Nickel and chromium had similar trends, however, the results were not significant.

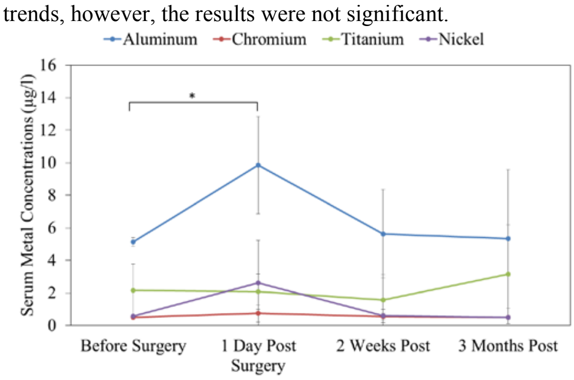

Figure 1: Mean (SD) metal serum levels from patients who underwent removal of metal surgery at four different time points (before surgery, 1-day, 2 weeks, and 3 months post op). * denotes significance ($p<0.05$)

CONCLUSIONS

Serum metal levels decrease in subjects who underwent removal of metal surgery to levels seen before surgery after three months. The goal of this study was to better understand metal ion release, origin, and clinical implications of metal ions in patients with spinal implants.

ACKNOWLEDGEMENTS

This research was funded by a grant from LifeHealth Care

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A MODEL-BASED RADIOSTEREOMETRIC ANALYSIS APPROACH TO MEASURING STABILITY OF A CEMENTLES METAL-BACKED PATELLA

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INTRODUCTION

Highly porous biological fixation surfaces have had mixed results in patella reconstructive surgery. Problems associated with loosening, dissociation of the metal backing, and increased poly wear have all been reported [1, 2]. Advancements in manufacturing techniques have introduced monoblock designs for patellar implants, which comprise a thicker poly layer and may improve results for cementless patellar components. To assess the early fixation of a metal-backed patella, a novel radiostereometric analysis (RSA) protocol was developed.

METHODS

RSA images from patients enrolled in an ongoing prospective clinical study entitled "A Prospective RSA and Clinical Evaluation of the Triathlon® Tritanium® Total Knee Replacement" (Stryker, Mahwah, NJ) were reviewed per the study protocol. Twenty-seven patients provided consent to participate in the study and underwent primary TKA with the Principal Investigator (SS) at Northwestern Medicine Central DuPage Hospital. Study patients received the Stryker® Triathlon® Tritanium® Total Knee Replacement. Three tantalum markers were implanted into the patella at the time of surgery using a specific bead placement protocol. RSA imaging exams occurred at post-op day 1, 6 weeks, 3 month, 6 months and 1 year following surgery.

During RSA imaging exams, to maximize the visibility of patella contours and tantalum markers, patients were positioned laterally, and the table was rotated 90-degrees, such that the patient's craniocaudal axis was parallel to an axis connecting the foci locations of the two x-ray tubes. To account for variability in knee flexion during lateral imaging, and variability in patellar orientation during surgery, patellar migration was measured in the implant based coordinate system (CS), which was custom aligned for each patient to the implant CS of the femoral component.

Bead visibility issues resulted in the exclusion of 6 patients from the analysis, leaving 21 patients in the final dataset.

RESULTS AND DISCUSSION

A large variation in patellar migration was seen between patients as early as the 6 week follow-up (Table 1). One patient showed a rapid rate of migration between 6 months and 1 year, whereas all other patients showed a trend towards stability, regardless of the quantity of the initial 6 week migration (Figure 1). It is not clear if higher migration will lead to clinical significance.

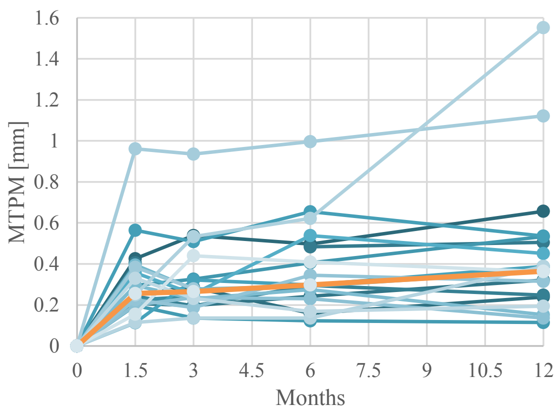

Figure 1: Patellar migration over the first post-operative year. Median migration is illustrated in orange.

CONCLUSIONS

The metal-backed patella showed a trend towards stabilization over the first post-operative year, but further follow-up is required.

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Table 1: Maximum total point motion (MTPM) of metal-back patella over the first post-operative year. N = 21

MTPM	1.5 months	3 months	6 months	12 months
Median	0.256 mm	0.265 mm	0.298 mm	0.365 mm
Range	0.113 - 0.961 mm	0.136 – 0.935 mm	0.122 – 0.997 mm	0.114 – 1.552 mm

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   Stryker Orthopaedics approved this study and provided funding to the institution (Central DuPage Hospital), but was not involved in data collection, analysis or interpretation.

LONG TERM FOLLOW-UP AFTER INSTRUMENTED BONE PRESERVING TOTAL ELBOW ARTHROPLASTY USING RADIOSTEREOMETRIC ANALYSIS

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INTRODUCTION

Early migration measured using Radiostereometric Analysis (RSA) might predict the long-term survival after total joint arthroplasty. However, if this applies to total elbow prostheses is unclear. We had previously reported migration data of sixteen Instrumented Bone Preserving (IBP) elbow prostheses in a prospective RSA-study with a follow-up time of two years. These short-term results showed micromotion of the humeral component in the first weeks but most components stabilized within six months postoperatively. The aim of the present study was to investigate the predictive value of early migrations of the IBP elbow prosthesis for revisions in the long-term. Additionally, survival data and clinical results were evaluated.

METHODS

Survival data of all sixteen patients were obtained. RSA images taken at baseline and 2 years postoperatively were used from the previous study. Migration of the humeral component was assessed by using marker-based RSA software (RSAcore, Leiden, The Netherlands) to determine total translation and rotation. To investigate the predictive value of early migration for future revision, the two-year migrations of revised prostheses were compared with migration data of the non-revised group. Patients who did not die or underwent revision surgery were invited for a single visit to our outpatient clinic, median 140 months (range 134 to 165) postoperatively. Clinical results were described using the Elbow Function Assessment (EFA), the Broberg and Morrey elbow functional rating index and the Oxford Elbow Score (OES).

RESULTS AND DISCUSSION

Five patients had died during follow up. Four prostheses were revised at a median follow up time of 95,5 months (range 60 to 129). Median total translation and rotation at two years follow-up was 0.16 mm and 1.26˚ in the revised prostheses and 0.68 mm and 2.00˚ in the non-revised prostheses. No significant difference was found between the two groups. Of the sixteen patients in the original study, seven were available for long-term follow-up measures. In five patients migration of the humeral component could be determined. Ten year migration results showed three stable and two unstable implants. The median EFA score was 58,5 (38 to 87), the median Broberg and Morrey score was 50,0 (29 to 88) and the median OES score was 32,0 (16 to 43).

CONCLUSIONS

We present the first long-term RSA results of the IBP elbow prosthesis. This study could not prove a relation between early migration of the humeral component of the IBP total elbow prosthesis and long-term survival of the prostheses. Unfortunately, we had a high loss of follow-up due to the high age of the patients. More extensive research into the role of RSA in the elbow joint is required to give more insight in early migration as a predictor of long-term survival.

THE INFLUENCE OF SUBJECT AND IMPLANT CHARACTERISTICS TIBIAL COMPONENT MIGRATION

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INTRODUCTION

Predictive models of long-term implant fixation in total knee arthroplasty (TKA) based on radiostereometric analysis (RSA) data have traditionally ignored the effects of patient demographics and implant factors which may influence the pattern and magnitude of implant migration. The objective of this analysis was to determine which implant and subject factors influenced overall migration of tibial components following TKA.

METHODS

Data were compiled from a registry of RSA data on primary TKAs (n = 367). Of this overall group, 222 implants were cemented and 145 uncemented in 153 male subjects and 214 female subjects. All subjects had a primary diagnosis of osteoarthritis and had RSA examinations over two years. No implants were revised during follow-up. Longitudinal data analysis using marginal models was performed to examine the influence of demographic and implant covariates while accounting for repeated measures of implant migration over time. Implant fixation (cemented or uncemented), age, sex, BMI, implant size, and smoking status were included in the model. Analyses were also performed on sub-groups of sex and implant fixation.

RESULTS AND DISCUSSION

In the overall group, only implant fixation had a significant effect on implant migration ($p < 0.001$). Examining migration curves of cemented and uncemented tibial components separated by sex shows increased migration for uncemented components in female subjects (Figure 1).

For uncemented tibial components in male subjects, smoking was significant ($p = 0.01$) and in the uncemented females group smoking ($p = 0.04$) and age ($p = 0.02$) affected implant migration. The effect of smoking in uncemented male subjects was to reduce the overall migration, while in female uncemented subjects the effect was reversed. Increasing age in uncemented females was associated with higher implant migrations. For cemented implants, no covariates were significant.

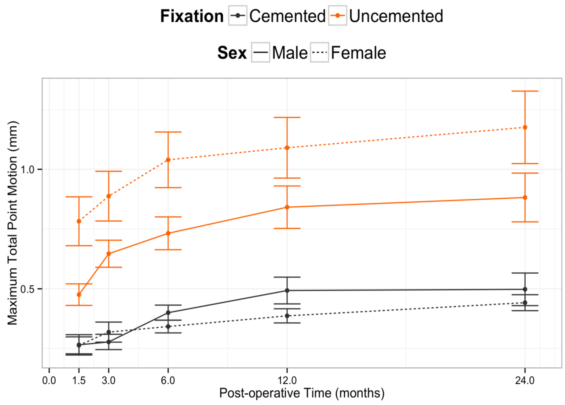

Figure 1: Implant migration for uncemented females (n=72), uncemented males (n=75), cemented males (n = 77), and cemented females (n = 145).

CONCLUSIONS

The migration of uncemented tibial components is more sensitive to subject factors than cemented implants. These differences are not consistent by sex, suggesting that it may be of value to evaluate male and female subjects separately following TKA.

ACKNOWLEDGEMENTS

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   Authors have received institutional research support from orthopaedic manufacturers (Stryker, DePuy, Wright Medical, Smith&Nephew, Zimmer).

EFFECTIVE RADIATION DOSE AND IMAGE QUALITY IN ROENTGEN STEREOPHOTOGRAMMETRIC ANALYSIS

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INTRODUCTION

In the majority of the published RSA papers the parameters of the roentgen technique are not provided. In addition, when radiation dose is provided, it remains unknown whether the absorbed radiation dose or the effective radiation dose (ED) is used [1,2,3]. Since the first publications about the radiation dose in RSA, roentgen systems have hugely improved and it is very well possible that the roentgen technique should be adjusted for the new modern systems to ensure the 'as low as reasonably achievable' (ALARA). Therefore, the objective of this study was 1) to determine the ED for current standard roentgen technique used in RSA and 2) to determine the ALARA roentgen technique without compromising image quality for RSA, by means of a phantom study.

METHODS

At the Reinier de Graaf Groep, Delft, The Netherlands, a Maxera Acetabular Cup with ceramic bearing (ZimmerBiomet, Warsaw, Indiana, The United States of America) was placed in a hemipelvic sawbone, the phantom. To simulate soft tissue for a standard adult pelvis, 21 cm [4] of Perspex plates were used to simulate the pelvis. A Piranha-meter (RTI, Mölndal, Sweden), was placed on top of the Perspex to measure the absorbed radiation dose. Roentgen images were acquired using a DX roentgen system (DigitalDiagnost, Philips, Best, the Netherlands). To determine the ED based on the absorbed dose, PCXMC software (STUK, Helsinki, Finland) was used. As standard roentgen technique [3], the following settings were used: no external tube filtration for both tubes, medio-lateral image of 73 kV and 25 mAs, for latero-medial image the settings are 90 kV and 12.5 mAs.
To determine the ALARA technique while maintaining sufficient image quality for RSA, the sawbone phantom was placed in a Perspex box filled with 24,8 cm water, which is the same as 21 cm Perspex [4,5]. RSA images with various roentgen settings (raising kV, mAs and external tube filtration) were taken with two DX roentgen systems (as above) to assess both image quality and ED. While the ED was calculated with PCXMC, the image quality was assessed by RSA with Model-based RSA software (version 4.1 RSA*core*, Dept. of Orthopaedics, LUMC, The Netherlands) version 4.1 with default installation settings.

RESULTS AND DISCUSSION

The ED with standard roentgen settings [3] resulted in an ED of 111 µSv. This ED is lower than the given 150 µSv reported by Teeuwisse [1]. However, the 150 µSv reported by Teeuwisse is based on unknown methods for calculating the ED.
The ALARA RSA hip roentgen settings were 102 kV and 8 mAs with external Cu + Al tube filtration for a standard patient using two DX systems.

CONCLUSIONS

1. The ED for THA RSA with standard roentgen settings as suggested by Valstar [3] is 111 µSv, which is lower compared to conventional radiographs.
2. For modern X-ray systems, setting for RSA x-rays can be optimized without a decrease in quality of the x-ray.

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APPLICATION OF TORSIONAL LOADS IN OVINE FRACTURE MODELS TO MEASURE STIFFNESS WITH RSA

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INTRODUCTION

Conventional radiography, while useful in indicating the presence of callus in repairing fractures, has been reported to be inconsistent with healing [1, 2]. A crucial factor for monitoring successful fracture healing is the mechanical environment partly determined by the relative stability of the fracture [3]. A number of studies have attempted to measure fracture stability *in vivo* via methods that do not directly measure the bone movement either side of the fracture (via external bone pins and strain gauges). Radiostereometric analysis (RSA) has been used to measure fracture fragment stability over time and more recently under the application of axial loads in a method termed Differentially Loaded RSA (DLRSA) [4]. Axial loads are not always the most appropriate way to test the stiffness of fractures treated with intramedullary rods. Hence the aim of this study was to design a torsional loading jig and determine the feasibility of testing the rotational stability of ovine tibiae under progressive loads.

METHODS

Sixteen skeletally mature merino sheep (6-tooth, 2 year old) underwent surgery and had a large tibial segmental defect created. The fracture defect was treated with intramedullary rod fixation and additional bone graft. Eight sheep received one type of bone graft (Treatment 1) while the other eight sheep received an experimental bone graft (Treatment 2). After 16 weeks in vivo, the treated and contralateral tibiae were retrieved.

The jig was designed to apply varying progressive loads via weights hanging off the wheel, while not obstructing simultaneous RSA images. (Figure 1). 16 treated tibiae were tested with IM rod fixation in place. RSA images were taken prior to loading (preload), under 2, 4, 6 kg loads and again unloaded (postload). The assessment of stiffness was made from RSA micromotion and torque applied by the jig (Nm/deg).

The 16 contralateral tibia were also tested under the same loads of fractured specimens in three stages,1)intact, 2)intact with fixation inserted and 3) fixed fracture model.

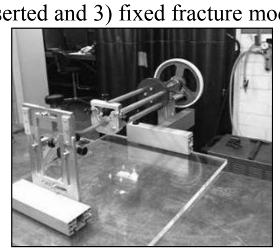

Figure 1: Tibial rotation jig for Differentially Loaded RSA

All RSA examinations were taken using dual simultaneous radiographs above a calibration cage (No43, RSABiomedical, UmRSA, Sweden). Subsequent pairs of radiographs were analysed using UmRSA software (v6.0, RSABiomedical).

RESULTS AND DISCUSSION

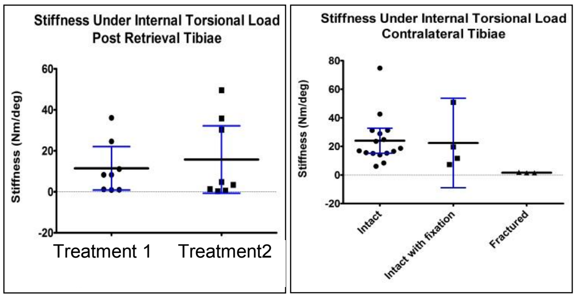

Figure 2: a) Apparent torsional stiffness of tibiae treated with either Treatment 1 or 2, and b) apparent torsional stiffness of contralateral tibiae tested from intact, intact with fixation and a fracture model.

Both treatment groups had variable apparent torsional stiffness measurements (Figure 2a). Individual tibia with increased stiffness did have more callous on retrieval. In addition the identification of differences between individual sheep who suffered adverse healing could be identified and were further confirmed through later histological examination. Differences were observed between contralateral tibiae tested from an intact state and then a fixed fracture model. This indicates the feasibility of this technique to identify changes in apparent stiffness during fracture healing allowing comparison between treatment groups.

CONCLUSIONS

The apparent stiffness of *ex vivo* ovine tibia was able to be measured using RSA while applying a progressive torsional load. The difference of stiffness values recorded in contralateral testing confirmed non-unions can be identified. The novel application of this technique may be used in future studies to examine lower limb fractures *in vivo*.

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The author(John Field) was chief investigator of a grant funding to test a new bone graft substitute which is currently blinded (Treatment 1 and 2) in the abstract.

TOTAL KNEE ARTHROPLASTY RSA IN THE STANDING LOW-DOSE BIPLANAR EOS X-RAY IMAGER

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INTRODUCTION

The EOS imager (EOS Imaging, Paris, France) is a low radiation dose biplanar X-ray slot scanner that has demonstrated reduced radiation dose by 6-9 times compared to conventional radiography. This imager scans patients in a weight-bearing position, provides calibrated three-dimensional information on bony anatomy, and may potentially limit the radiation exposure during serial RSA studies. The EOS imager has a larger pixel size than current digital RSA systems and the vertical translation of its scanning X-ray head may impact the accuracy and precision of the RSA technique. After promising results in a phantom study, this pilot study was initiated with the goal of determining the double exam precision of total knee arthroplasty (TKA) patients in the EOS, and whether it is possible to obtain clinically relevant precision in this modality.

METHODS

At a mean of 4.1 years post-surgery (2.8 to 5.2), 13 TKA participants (14 knees, mean age 67 years (50 to 76), 9 female and 5 male) who have already had RSA beads implanted were scanned twice in the EOS imager. Initially participants were scanned using standard EOS clinical protocols with increased kVp to aid in bead visibility over the implant. As preliminary analysis showed unacceptable levels of motion for clinical use, incremental changes to the scanning protocol were implemented: an acrylic support from the foot to mid-calf, an increase in scan speed up to four times the clinical standard during imaging, and a calibration object was attached to the leg to allow for correction of motion artifacts during post-processing. Faster scanning reduces dose and introduces vibration into the system, giving rise to concerns that the images would not be of sufficient resolution for RSA. We examined whether this decrease in resolution impaired the double examination precision to a greater extent than patient motion at lower speeds.

RESULTS AND DISCUSSION

One subject had no migration calculated due to poor bead matching and was excluded. Due to the tibial slope, beads in the polyethylene were often obscured by the implant, and only two matched markers in the implant were available for many exams. Three beads are needed for rotation precision. Table 1 gives the number of exams used for each precision analysis. Overall the upper limit of the 95% confidence interval precision was 0.37, 0.14, and 0.50mm in the x, y, and z planes, respectively and 0.35, 0.17, and 0.24° in R_x, R_y, and R_z. For the subset scanned at 2 to 4 times the speed of clinical exams with acrylic stabilization the precision was calculated to be 0.12, 0.05, and 0.13mm for translation, and 0.17, 0.11, and 0.32° for rotation. One participant at a faster speed had motion artifacts (calculated migration more than double the precision) which were successfully removed with post-processing.

CONCLUSIONS

In vivo RSA in the EOS imager is capable of ≤ 0.5mm and ≤ 0.35° precision. With faster speeds and additional stabilization support, this pilot study suggests an RSA precision of ≤ 0.13mm and ≤ 0.32°, well within published uniplanar values for arthroplasty RSA, with the benefit of greater precision in the z-plane that a biplanar setup offers.

ACKNOWLEDGEMENTS

This study was funded by the Atlantic Canada Opportunities Agency Atlantic Innovation Fund (#199377). The authors would also like to acknowledge the assistance of the Laboratoire de recherche en imagerie et orthopédie research team (Montreal, Canada) under the direction of Jacques de Guise, and the assistance of Halifax Biomedical Inc. (Mabou, Canada) and EOS Imaging (Paris, France) for their expertise and contributions of matching funds to the Atlantic Innovation Fund.

Table 1: Precision of TKA double exams in the calibrated EOS imager, quoted as upper 95% confidence interval

	x	y	z		Rx	Ry	Rz
Precision of all TKA double exams	0.37mm	0.14mm	0.50mm	0.25mm	0.35°	0.17°	0.24°
n double exams	13				9		
Precision of high speed subset double exams	0.12mm	0.05mm	0.13mm	0.09mm	0.17°	0.11°	0.32°
n double exams	6				5		

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A selection of preliminary 1 year post-operative RSA-data of the Persona versus NexGen TKP-study: does the novel design perform just as well?

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INTRODUCTION

Osteoarthritis, rheumatoid arthritis or trauma of the knee can lead to intense pain and loss of function. The majority of patients who suffer from these conditions experience pain reduction and restored function after receiving a Total Knee Prosthesis (TKP).

The NexGen TKP (Zimmer, Warsaw, Indiana USA) has been a proven design since its introduction well over a decade ago [1,2]. However, Zimmer has recently introduced the Persona TKP, which the manufacturer claims is an improved design and is supposed to be the follow-up of the NexGen TKP. The novel design has been successfully used in about 20.000 patients, but has never been analyzed in direct comparison with its predecessor in a Randomized Controlled Trial. The aim of this study is to assess and compare the migration of these two designs, as well as to compare clinical data, patient reported outcome measures, kinematics, and prosthesis placement. This abstract will focus on the currently available 1-year migration results.

METHODS

Patients with primary or secondary osteoarthritis of the knee who were planned to receive a primary total knee replacement were eligible for inclusion. They were randomized after providing informed consent to receive either a (standard) fixed bearing, cemented NexGen or a (novel) fixed bearing, cemented Persona TKP.

For RSA measurements, 5 to 8 tantalum markers were inserted into the distal femur and proximal tibia region during surgery. Patients were kept from weight bearing until after the first RSA radiograph was taken on the first or second postoperative day, and were allowed full weight bearing afterwards using crutches. RSA radiographs were taken at 3 and 6 months, 1 year and annually thereafter.

RESULTS AND DISCUSSION

Of the 75 included patients, 31 patients have 1 year postoperative RSA results of the tibia available (17 left knees, 17 NexGen), 28 patients had 1 year data of the femur-component (15 left knees, 16 NexGen). The results are represented per prosthesis type received in Table 1.

There were no significant differences in translations, rotations or MTPM between the two groups at 1 year ($p > 0.05$). We also analyzed the available pre-operative and 1-year's Patient Reported Outcome Measures (PROMs) of the Knee-injuries and Outcomes of Osteoarthritis Score (KOOS) and Oxford Knee Score (OKS). For both the KOOS as well as OKS there were no significant differences between the two groups for the pre-op as well as the 1-year follow-up scores. All patients at 1 year follow up or over still have their implant in situ, and none of these patients reported severe complaints of the affected knee or have other indications that revision is needed. One patient had a prolonged hospital stay after surgery due to loss of sensation in both legs, related to a problem with the epidural.

CONCLUSIONS

Based on the available 1 year follow-up data we see no clinically or statistically significant difference between the standard NexGen and the novel Persona TKP.

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Table 1: available mean RSA results (Mean (SD)) 1 year after surgery for all cardinal axes and MTPM (in millimeters or degrees)
Tx = Medial-Lateral Translation, Ty = Distal-Proximal Translation, Tz = Posterior-Anterior Translation
Rx = Anterior-Posterior Tilting, Ry = Axial Rotation, Rz = Medial-Lateral Tilting

Prosthesis		Tx (mm)	Ty (mm)	Tz (mm)	Rx (deg)	Ry (deg)	Rz (deg)	MTPM
NexGen	tibia	-0.01 (0.29)	-0.04 (0.19)	0.06 (0.29)	-0.05 (0.43)	-0.07 (0.52)	0.04 (0.22)	0.99 (0.55)
	femur	0.15 (0.31)	0.20 (0.21)	-0.09 (0.49)	0.28 (0.43)	-0.14 (0.31)	0.11 (0.43)	1.59 (1.43)
Persona	tibia	0.00 (0.21)	0.05 (0.18)	-0.06 (0.28)	0.07 (0.49)	-0.12 (0.31)	0.01 (0.29)	0.79 (0.32)
	femur	-0.09 (0.34)	0.14 (0.22)	0.06 (0.26)	0.20 (0.33)	-0.04 (0.52)	-0.06 (0.31)	0.90 (0.39)

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MONOBLOCK POSTERIOR STABILIZED VS CRUSCIATE RETAINING TRABECULAR METAL TIBIAL COMPONENT

RSA study with 9 to 10-years follow-up

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INTRODUCTION

Uncemented cruciate retaining (CR) trabecular metal tibial implants have shown excellent clinical results up to 10 years in patients younger than 60. This may be due to inherent properties of the trabecular metal, seemingly enhancing biologic fixation. Posterior stabilized (PS) implants normally achieve larger knee flexion compared to CR, which would be beneficial for the younger patient. For cemented implants, however, PS designs have shown higher revision rates compared to CR, perhaps due to larger forces at the interface. The primary aim of the study was to determine the migratory pattern of the NexGen LPS-Flex Trabecular Metal Monoblock tibial component up to 9 year and compare with 10 year data recently published on the CR version of the same implant [1].

METHODS

This is a prospective study of 40 patients (20 women, 20 men, 49 knees) consecutively operated by one surgeon between 2007 and 2008. Mean age (range) was 55 (40-60) years. 20 knees had primary osteoarthritis (OA) and 29 knees had OA secondary to meniscal or ligament injuries, patellar instability or knee fracture. Follow-up was 9 years. RSA was performed within 3 days postop., and thereafter at 6 weeks, 3, 12, and 24 months, and 5 and 10 years. Tantalum markers were inserted into the monoblock tibial polyethylene and in the metaphysis of tibia. Rotations of the implant, MTPM, maximum subsidence of the periphery of the implant and translation of the center of the implant along the vertical axis of the knee were examined. The change in MTPM between 1 and 2 years, and between 2 and 5 years was calculated. The interface between implant and bone was classified according to Hayakawa [2].

RESULTS

The PS implants displayed similar pattern of migration as found for other uncemented implants; early migration and later stabilization. Rotation around the x and z axes was associated with a mean subsidence of the center of the tibial tray of 0.34 (CI 0.10) mm and a maximum subsidence of the periphery (usually posteriorly) of a mean 0.63 (CI 0.21) mm. Lift-off of the edge of the tibial tray was small and occurred only occasionally, mostly anteriorly. Between 1 and 2 years one implant displayed MTPM > 0.2 mm, and between 2 and 5 years 4 implants displayed MTPM > 0.3 mm.

Comparing the PS implant with the CR version [1] one can see that the pattern of migration was very similar, however the time for the initial settling was a little bit longer for the PS implants. This is verified by the change in MTPM from 3months, 12 months and 24 months to 9 years being significant (p< 0.01) whereas the change in MTPM between 5years and 9 years was insignificant (p=0.46). 49 knees were classified Hayakawa A or B, and only 3 Hayakawa C

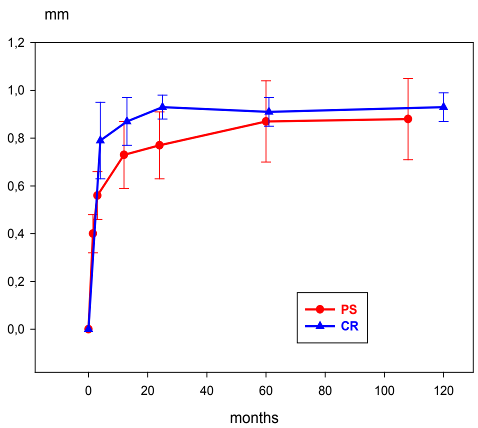

Figure 1: MTPM in the posterior stabilized (PS) and cruciate retaining (CR) implants.

DISCUSSION

In contrast to cemented PS implants, trabecular metal PS implants display a benign pattern of migration at least as good as it CR counterpart, which is compatible with good long-term prognosis as regards fixation. This is also corroborated with the benign implant bone interface. This may be due to inherent properties of the trabecular metal, seemingly enhancing biologic fixation.

ACKNOWLEDGEMENTS

Study partially sponsored by Zimmer-Biomet

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   The study was partially funded by Zimmer Biomet

MIGRATION AND RADIOLOGICAL APPEARANCE OF UNCEMENTED TRITANIUM TIBIAL COMPONENTS – ONE-YEAR RESULTS OF A RANDOMISED RSA STUDY

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INTRODUCTION

Tibial component loosening remains a substantial problem in total knee arthroplasty (TKA). A possible solution is the use of uncemented highly porous titanium implants, which have shown to promote bone ingrowth resulting in a durable biologic fixation. We present the preliminary one-year results of a randomised RSA study evaluating Tritanium tibial baseplates; a new material introduced for uncemented TKA.

METHODS

Seventy patients were randomised to either cemented Triathlon cruciate retaining (CR) or uncemented Tritanium Triathlon CR TKA (Stryker, NJ, USA). The highly porous Tritanium tibial component is designed with four additional (porous) pegs surrounding the stem. Radiostereometric analysis (RSA) and clinical scores (the Knee Society Score, the Forgotten Joint Score and the Knee Osteoarthritis and Injury Outcome Score) were evaluated at baseline and postoperatively at three months and one year of follow-up. A linear mixed-effects model was used to analyse the repeated measurements.

RESULTS AND DISCUSSION

In half of the Tritanium cases, regions with reduced periprosthetic bone density were identified on conventional x-rays after both three months and one year of follow-up (Figure 1). The cause of this apparent reduction in bone density is unknown but might be only temporarily due to bone ingrowth into the adjacent metal. Further investigations to objectify these radiographic signs are planned. Both groups showed

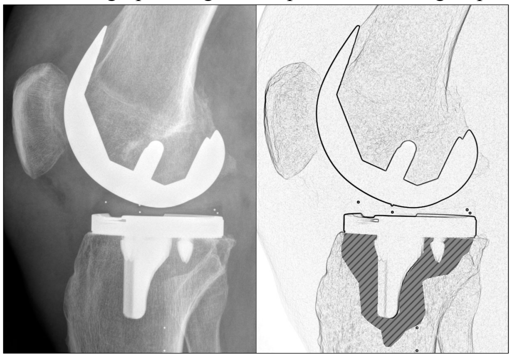

Figure 1: Lateral x-ray and schematic view of a Tritanium tibial component at three months follow-up showing periprosthetic radiolucent regions (shaded area).

comparable improvements on all clinical scores over time. There were no differences in mean migration between groups with a mean Maximum Total Point Motion (MTPM) of 0.47 mm (95% CI, 0.39 to 0.55) for the cemented group and 0.55 mm (95% CI, 0.46 to 0.64) for the Tritanium group at one year follow-up ($p = 0.24$). Two cemented components showed ≥1.0 mm of migration at one year follow-up compared with four Tritanium components, of which three (T2-4) appeared to have been stabilised between three months and one-year follow-up (Figure 2). However, progressive migration was seen in one malaligned Tritanium component (T1, with a postoperative posterior slope of 10°) showing migration up to 3.9 mm MTPM and 7.8° of posterior tilt (Figure 2). This patient has complaints of instability; revision surgery is postponed on patient request after receiving a brace.

CONCLUSIONS

Migration of Tritanium tibial components stabilises within one year, even in three cases showing high initial migration, suggesting adequate bone ingrowth. However, in one malaligned case, the Tritanium design could not prevent progressive migration. Periprosthetic reduction in bone density was seen in half of the cases, warranting further investigation.

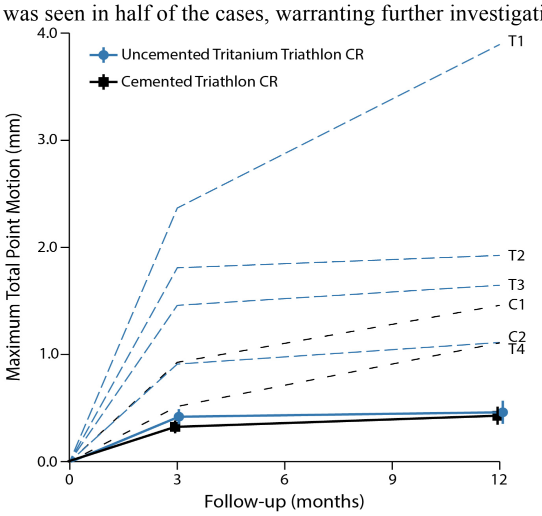

Figure 2: RSA data showing the mean MTPM and 95% CI for the groups; excluded from the groups are individual components showing > 1 mm of migration at 12 months follow-up: T1-4 (Tritanium) are the dashed blue lines and C1-2 (Cemented) are the dashed black lines.

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FULLY AUTOMATED "LIVE" RSA ANALYSIS IN THE RADIOGRAPHY ROOM: PRACTICAL EXPERIENCE AND COMPARISON TO MANUAL MEASUREMENT

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INTRODUCTION

Analysis and radiography for Radiostereometry (RSA) are two techniques that require special expertise to get good results. Analysis is typically time consuming and can be particularly difficult for complex bead patterns. Radiography may result in imperfect image pairs which may in fact be technically sufficient or may not be fully analyzable and require repeat imaging. If this is known in the radiography room, the radiographer could judge when to repeat the procedure after necessary adjustment. However if not repeated at the time then the patient would need a return visit to the clinic at a later date, requiring extra time and expense, otherwise data points would be lost weakening the power of the study.
Traditionally RSA analysis is carried out in a measurement laboratory and is not available at the time of the patient visit.
Over the last few years we have developed a new fully automatic method which retrieves, anonymizes, catalogues and analyses the images from the moment of acquisition within the x-ray room. Quality assurance (QA) information is presented to the radiographer showing if the x-rays pass RSA adequacy, or in what aspects they fail. In addition, for follow up visits, a full kinematic analysis is available immediately to the clinical staff. This paper describes our experience over the last year using this automated method for live analysis of patient RSA x-rays in the radiography room. It also assesses the accuracy of automated measurement compared to manual measurement.

METHODS

RSA images were acquired on the AdoraRSA (NRT, Denmark) using Canon CXDI-50C detectors and Canon PC software version 7. After acquisition the images are automatically transferred to the analysis PC (a standard Intel i5, windows 10 desktop). Analysis software was written in IDL version 6.3 (Harris Geospatial Solutions, USA). The software recognizes the calibration markers and the patient markers. Where the patient has previous RSA analsyis data, the object markers are labelled matching the previous RSA and a kinematic analysis may be output immediately. Spherical implants such as prosthesis bearing heads can also be measured automatically at this stage.
Tests were carried out using calibration boxes 10, 41 and 43 (RSA Biomedical AB, Sweden). The method has been used live, i.e. to provide immediate in radiography suite analysis, on 10 revision hip and 11 shoulder patients, using boxes 43 and 41 respectively.
The automated analysis was compared to manual measurement. In addition hip and shoulder phantoms have also been imaged in widely varying positions, and the automated software tested. Image classification was considered perfect where markers were correctly labelled and within 10 microns of the manual measurement, and *adequate* if markers were correctly identified and labelled but within 0.3mm of the manual measurement.

RESULTS AND DISCUSSION

Complete automated analysis was achieved within 25 to 40 seconds of image acquisition.
The radiographers routinely made a test image prior to the patient being imaged to confirm adequacy of set up. This was 96% correctly reported by the software. The failures were normally due to overexposure of the test.
84 patient image pairs were followed with the automated software. 77 (92%) of image pairs films were correctly measured. There were no cases of where image pairs had been passed, but were subsequently found to be insufficient.
Approximately 6% of markers were correctly identified but poorly measured. Generally these markers were near metal implants or other markers, and so had edge and double markers models added in the manual measurements for accurate measurement [1]. Such markers can usually be identified in terms of the quality of detection and proximity to other objects, and could have had model refinements applied. For the live kinematic analysis, these differences are usually not critical due to the marker redundancy.
With the phantom experiments 284 out of 300 (95%) of image pairs were correctly identified needing only adjustment for close markers.
The method is suitable for optimization, which could dramatically increase analysis speed. It could easily be applied to large dynamic RSA data sets, radically reducing analysis time and effort. We have also found it highly effective at labelling markers which are clustered in a complex pattern which makes manual labelling challenging.
Manual review of the automated measurements is fast. Moreover, it may not be required with further development of post-analysis techniques.

CONCLUSIONS

Reliable automated RSA has been achieved and applied effectively within the radiography room. This has allowed immediate feedback on image quality for RSA, and given instant RSA kinematic results. We are optimistic that further improvements can be made.

ACKNOWLEDGEMENTS

We would like to thank NRT and Canon for their technical assistance during this project.

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RADIOSTEREOMETRIC ASSESSMENT OF HEALING IN PROXIMAL HUMERAL FRACTURES

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INTRODUCTION

Sufficient early stability of proximal humeral fracture (PHF) is an important factor in outcome. In principle, fracture stability can be assessed using radiostereometric analysis (RSA).

Our planned clinical study will follow patients who have received plated internal fixation for a proximal humeral fracture using a CF-PEEK implant, which being radiolucent will aid visualization of the fracture. We will investigate whether there are changes in stability of the fracture during healing. In particular, the stability of the fracture fragments and plate under the loading conditions produced by patient rehabilitation exercises. To make these assessments the patient will be imaged standing, first with their arm by their side, and then raised in flexion or abduction by 45 to 90 degrees. The implication for RSA is that the imaged object position will differ widely in both rotation and translation throughout the imaging volume during the examinations. The accuracy of RSA may be affected by positional changes between images, by size of the fracture segments studied and by the visibility of the tantalum markers which may be occluded by metal plates and humeral plate. The aim of this in-vitro study was to assess these errors so that we could determine whether the proposed technique would be feasible for use in a clinical study.

METHODS

In order to simulate a rigidly fixed three and four part proximal humeral fracture, a phantom was constructed from a humeral orthopaedic bone model (Sawbones, Washington USA) to which a "Piccolo" CF-PEEK Proximal Humeral Plate (Carbofix Orthopaedics) was fixed using titanium screws. Tantalum markers of size 0.8mm and 1.0mm were inserted into the bone: six into the greater tuberosity, five into the lesser tuberosity, seven into the head, and ten in the shaft.

The phantom was mounted in an upright RSA setup comprising AdoraRSA (NRT, Denmark) with Canon CXDI-C detectors and calibration box 43 (RSA Biomedical AB, Sweden) in an upright setting (figure 1). Our calibration box was previously recalibrated by imaging a known object, and we will present the results of using both the original and recalibrated box files.

The phantom was imaged at 5 examination protocols: rest (0 degrees flexion and abduction), abduction of 45 and 90 degrees (A45 and A90), and flexion of 45 and 90 degrees (F45 and F90). Each position was repeated 16 times with repositioning of 1-3 cm and 1-5 degrees and with repositioning of the x-ray setup.

Movement between segments was calculated with each rest exam as reference compared to all the other exams. Since the phantom is a rigid model, any detected movement is considered error.

RESULTS AND DISCUSSION

The condition numbers (CN) for the fracture segments were shaft 38, head 37, greater tuberosity 65 and lesser tuberosity 103.

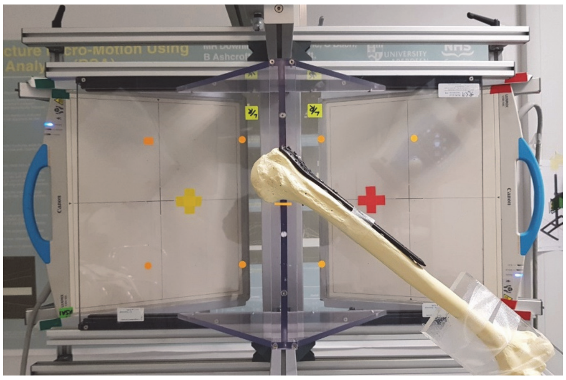

Figure 1. RSA setup with phantom set to 45 degrees abduction.

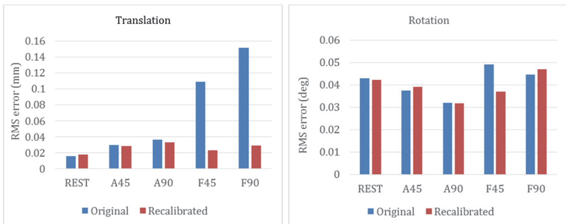

Figure 2. Total translation and rotational errors for head vs shaft before and after calibration box recalibration.

The flexion protocols F45 and F90 showed high total error (0.16mm RMS) when using the original box calibration data (figure 2), however when the box was recalibrated this error reduced to only 0.03mm, similar to the error within rest exams. The total error 95% uncertainty of measurements between differing position protocols was better than 0.1mm when comparing fracture segment motions to the shaft reference segment. Smaller segments with higher condition number CN had poorer rotational accuracy, but translation was not affected where the reference segment had a low CN.

For this study a fixed model was used to explore the total error (precision plus bias) by wide variation of the phantom position. We believe this is a more rubust method of assessing RSA error than experiments using micrometer determined movements.

CONCLUSIONS

Previous studies of induced fracture micromotion have observed between 0.1mm and 1.2mm [1,2], so we conclude this clinical protocol should be suitable for assessment of proximal humeral fracture stability and healing.

ACKNOWLEDGEMENTS

This study was funded by Invibio Biomaterial Solutions.

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2. Callary SA, et al, *World J Orthop.* 4(4):259-266, 2013.

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2. Invibio Biomaterial Solutions, (USA) funded Aberdeen University (to which the authors are affiliated and or employed by) to carry out investigator led research into the Piccolo" Proximal Humeral Plate replacement

TIBIAL COMPONENT MIGRATION IN TOTAL KNEE REPLACEMENT PERFORMED USING GAP BALANCING AND MEASURED RESECTION TECHNIQUES

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INTRODUCTION

Surgeons generally perform total knee replacement using either a gap balancing (GB) or measured resection (MR) technique. In gap balancing, ligamentous releases are performed first to create an equal joint space before any bony resections are performed. In measured resection, bony resections are performed first to match anatomical landmarks, and soft tissue releases are subsequently performed to balance the joint space. Previous studies have found a greater rate of coronal instability and femoral component lift-off using the MR technique [1], but it is unknown how these potential differences in loading translate into component fixation.

METHODS

Patients were randomly assigned at the time of referral to a surgeon performing either the GB or MR technique (n = 12 knees per group). Both groups received an identical cemented, posterior-stabilized implant (Triathlon, Stryker, Kalamazoo, MI, USA). At the time of surgery, marker beads were inserted in the bone around the implants to enable radiostereometeric analysis (RSA) imaging. Patients underwent supine RSA exams at 0-2 weeks, 6 weeks, 3 months, 6 months, 12 months, and 24 months. Migration of the tibial component within individual planes as well as maximum total point motion (MTPM) was calculated using model-based RSA software.

RESULTS AND DISCUSSION

At 1 year, there was no significant difference in MTPM of the tibial component ($p = 0.77$, Figure 1) between the MR group (0.66 ± 0.30 mm) and the GB group (0.69 ± 0.24 mm). At 2 years, there was a significant difference ($p = 0.02$) between the MR group (0.48 ± 0.24 mm) and the GB group (0.88 ± 0.40 mm), although some patient exams are outstanding in both groups. The mean difference in MTPM between 1-2 years for the MR group was -0.17 mm ($p = 0.14$) and for the GB group was 0.19 mm ($p = 0.28$). There were no differences at 2 years between groups within individual planes (Table 1).

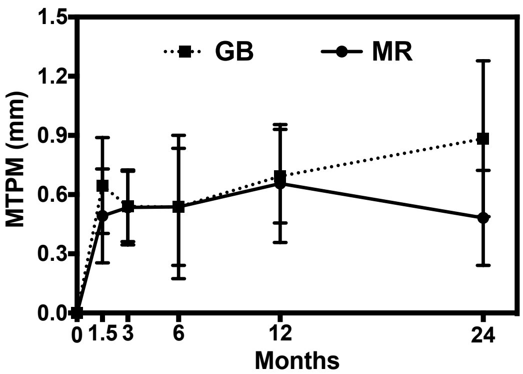

Figure 1: Maximum total point motion (MTPM, in mm) over 2 years post-operation. Error bars are standard deviation.

CONCLUSIONS

Using the Pijls et al. [2] criteria for acceptable early migration predictive of <3% revision rate at 5 years, both the GB and MR groups are at the low end of the at risk category (>0.54 to <1.6 mm of MTPM at 1 year). Using the Ryd et al. [3] criteria of <0.2 mm of MTPM between years 1-2, both groups demonstrate acceptable early migration. Although some differences were found between the GB and MR groups, these are most likely not clinically significant, therefore both techniques provide acceptable fixation for TKR.

ACKNOWLEDGEMENTS

This study was funded by the Western University Department of Surgery Internal Research Fund.

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Table 1: Translations (in mm) and rotations (in deg) within individual planes at 2 years, reported as mean ± standard deviation.

	Tx	Ty	Tz	Rx	Ry	Rz
GB	0.09 ± 0.35	-0.06 ± 0.12	0.05 ± 0.31	-0.24 ± 0.37	0.40 ± 0.72	0.04 ± 0.43
MR	0.01 ± 0.17	0.01 ± 0.15	0.06 ± 0.12	-0.04 ± 0.20	-0.07 ± 0.47	-0.05 ± 0.31
p Value	0.52	0.46	0.97	0.16	0.12	0.64

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   Dr. Howard is a paid consultant to DePuy and Stryker. Dr. Lanting is paid consultant to DePuy, Integra, IntelliJoint, Smith & Nephew, and Stryker.

2. A commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

   London Health Sciences Centre receives institutional research support from DePuy, Smith & Nephew, and Stryker.

FEASIBILITY OF MODEL-BASED RSA OF THE TIBIAL COMPONENT OF BICRUCIATE RETAINING TKA

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INTRODUCTION

Bicruciate retaining (BCR) total knee arthroplasty (TKA) is a specialized implant that preserves both cruciate ligaments. In BCR implants, the tibial component is typically smaller in the distal to proximal dimension due to anatomical restriction of the preservation of the cruciate ligaments (Fig 1). This may potentially influence stability, and its measurement, of the tibial component. The aim of this study was to determine the feasibility of measuring migration of the tibial component of BCR TKA.

METHODS

For a phantom study, the cruciate retaining (CR) and BCR model of the Vanguard TKA (Zimmer-Biomet, Warsaw, USA) were individually implanted on a sawbone, and 5 1-mm tantalum markers were fixed to the exterior of the tibia of the sawbones. Each sawbone was imaged in 6 supine positions ranging from 45° external rotation to 45° internal rotation. For both sawbones, paired migration was calculated between the six positions to calculate the accuracy of the measurements (in standard deviation). Model-based RSA version 4.10 (RSAcore, Leiden, The Netherlands) was used with CAD models of the tibial components. For a feasibility study, 4 cases (2 CR and 2 BCR implants) were selected from a larger RCT [1] (e.g. Fig 1).

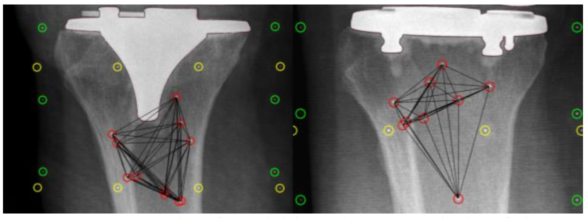

Figure 1: Example of model-based RSA analysis of the CR (left) and BCR (right) tibial component in situ.

For all cases, migration was measured from directly postoperative to 6 weeks (double RSA for precision), 3 months, 6 months, and 12 months.

Outcome is reported as translation (mm), rotation (º), maximum total point motion (MTPM, mm), total translation (TT, mm), and total rotation (TR, º). Precision was calculated as 1.96·SD [3].

RESULTS AND DISCUSSION

Concerning the accuracy of the measurements, the SDs were comparable between the CR and BCR implant (Table 1). Translations of 0.06 mm and rotations of 0.75˚ were feasible. In the patients, the measured TT and TR were comparable between the CR and BCR implant (Fig. 2). MTPM of the implants ranged from 0.16 to 0.64 and are comparable to those reported in literature [2]. At the time of the conference, more data will be available.

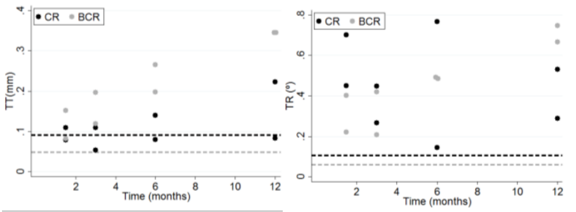

Figure 2: TT (left) and TR (right) of the implants for 4 cases at follow-up. Dashed lines show the precision.

CONCLUSIONS

Measuring migration of the tibial component of the BCR implant is feasible with acceptable accuracy and precision for translation and rotation.

ACKNOWLEDGEMENTS

We would like to acknowledge Zimmer-Biomet for providing implants for the phantom study and the department of radiology of our hospital for assisting with the RSA imaging.

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Table 1: Results of the phantom study. For each implant the standard deviations of the paired migrations are reported for all translations (T), rotations (R), and MTPM. The mean condition numbers (SD) of the series are shown for each implant.

Implant	Tx	Ty	Tz	Rx	Ry	Rz	MTPM	TT	TR	Con#
CR	0.06	0.04	0.05	0.10	0.75	0.11	0.33	0.02	0.46	54 (5.69)
BCR	0.04	0.04	0.05	0.27	0.12	0.22	0.07	0.01	0.16	36 (1.36)

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   Part of this study was financially supported by Zimmer-Biomet (payments to hospital, research department). Zimmer-Biomet was not involved in interpretation, analysis and presentation of the results of this study.

A Prospective Consecutive Series Assessing Migration and Rotation of the Absolut Cemented Femoral Stem

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INTRODUCTION

Building on the success of force-closed stem designs, the Absolut femoral stem is a new highly polished, double tapered, collarless cemented femoral stem for Total Hip Arthroplasty.

This study aims to investigate safety, micromotion patterns, bone remodelling and clinical scores for this implant compared to established predecessors.

METHODS

This is a prospective, consecutive series clinical outcomes study incorporating 51 patients with a mean age of 74 and a mean BMI of 26. All operations were carried out by one experienced arthroplasty surgeon in a standardised setting and all patients received an Absolut cemented femoral implant.

Patients were evaluated preoperatively, as well as postoperatively at 6 weeks, 3, 12 and 24 months, with a combination of RadioStereometric Analysis, DEXA and clinical scores (Harris and Oxford Hip Scores, SF-12, active hip range of motion) to evaluate stem micromotion, bone density changes and clinical function of the implants.

RESULTS AND DISCUSSION

At interim analysis the stem showed a median subsidence of 0.65mm, 1.06mm and 1.41mm at 3, 12 and 24 months, respectively. Median posterior translation of the prosthesis head (retroversion) was 0.44mm, 0.37mm and 0.32mm at 3, 12 and 24 months and varus/valgus displacements were negligible. This migration pattern falls within expected and acceptable boundaries for this type of stem.

DEXA has demonstrated no significant changes in mean BMD across 7 Gruen zones at 12 or 24 months, indicating good maintenance of bone density.

PROMs have improved after surgery in typical arthroplasty fashion. The mean Oxford Hip Score improved from 25 preoperatively to 37, 43, 46, 46 at 6 weeks, 3, 12 and 24 months and the mean Harris Hip Score improved from 54 preoperatively to 81, 92, 93, 92 at 6 weeks, 3, 12 and 24 months. No revisions have been carried out to date.

CONCLUSIONS

The Absolut cemented femoral stem shows good adherence to established and expected patterns of stem micromotion. Minimal bone density changes consistent with stress shielding have been observed to date. Clinical scores are improving well with high patient satisfaction. All outcome measures indicate good stability and performance at this time.

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- Study funded by industry through Hollywood Private Hospital Research Foundation

PRECISION OF BONE MODELS IN DYNAMIC RSA OF THE ELBOW AND FOREARM

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INTRODUCTION

Dynamic radiostereometric analysis can be used to quantitatively measure changes in the three-dimensional *in-vivo* movements of bones, which can provide insight in the kinematics relevant for both diagnostics and the development or validation of new implants. However, analysis of the radius and ulna bones in both the elbow and forearm is challenging due to the long predominantly cylindrical shape. Using marker-based RSA, it is difficult achieve acceptable condition numbers, especially in patients. A markerless technique based on CT bone models is of great clinical interest. Using digitally reconstructed radiograph (DRR) based RSA, the position and orientation of the bones can automatically be optimized [1].

The aim of this study was to validate the precision of DRR based RSA compared to marker-based analysis.

METHODS

For both the distal forearm (11 arms) and elbow (8 arms), a specialized motorized fixture was designed to perform clinically relevant motions. Each arm was CT scanned and subject specific bone models were created from automated segmentations [2]. Tantalum markers were inserted for marker-based analysis. Automated analyses were performed with custom developed AutoRSA software using DRR based image registration and a multi-resolution multi-stage optimization strategy. The method is GPU accelerated and multiple bones are simultaneously imaged. Model-based RSA (RSAcore) was used to calibrate and initialize the bones in the first frame of the dynamic recording. The complete recording was subsequently analyzed by initializing each frame with linear extrapolation from the previous frame. Marker analysis was independently performed in 3 scenes per recording at the start, middle, and end of the movement. Comparisons with marker-based analysis were performed with paired-migrations. Precision was evaluated as systematic bias (mean difference) and random error (1.96*SD) for translations and rotations.

RESULTS AND DISCUSSION

For the elbow joint a small systematic bias ($p<0.05$) was found for all translations of the ulna and Tx and Tz for the radius (Figure 1). No systematic bias was found for the translations or rotations of the forearm or the humerus in the elbow ($p>0.05$). Precision data (random error) is shown in Table 1.

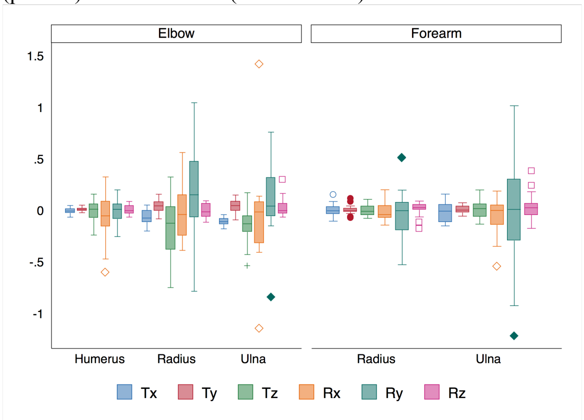

Figure 1: Box plots of translations [mm] and rotational [°] errors (systematic bias) for the elbow and forearm with respect to marker-based analysis.

CONCLUSIONS

DRR based RSA analysis provides a good precision of ≤1° and ≤0.55 mm in the elbow and ≤0.18mm in the forearm. The method can therefore be used for automated analysis of markerless dynamic RSA studies for both pre-operative diagnostics or post-operatively for analysis of joint and implant kinematics.

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2. De Raedt, et al., *Proceedings SPIE.* **8670**, 2013.

Table 1: Overview of the precision (random error) for translations [mm] and rotations [°] for the elbow and forearm.

	Elbow (n=16)						Forearm (n=22)					
Bone	**Tx**	**Ty**	**Tz**	**Rx**	**Ry**	**Rz**	**Tx**	**Ty**	**Tz**	**Rx**	**Ry**	**Rz**
Radius	0.16	0.13	0.55	0.49	0.92	0.13	0.12	0.08	0.10	0.17	0.50	0.13
Ulna	0.08	0.13	0.36	1.00	0.76	0.19	0.18	0.07	0.17	0.36	0.97	0.26
Humerus	0.06	0.04	0.21	0.45	0.23	0.09	-	-	-	-	-	-

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   NONE

STABILITY ASSESSMENT OF A NEW KNEE REPLACEMENT PRODUCT USING RADIOSTEREOMETRIC ANALYSIS

The Canadian RSA Network
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INTRODUCTION

A prospective clinical trial utilizing radiostereometric analysis (RSA) was initiated to study the early fixation of a cemented total knee replacement (TKR) (Attune, DePuy) shortly after its clinical release in order to evaluate the safety and efficacy of the device. The primary objective of this study was to determine the migration of the tibial baseplate using model-based RSA (MBRSA) up to 2-years post-operative and compare against published thresholds for acceptable (<0.5 mm), at risk (0.5 mm to 1.6 mm), and unacceptable (>1.6 mm) of maximum total point motion (MTPM) at 12 months [1]. Improvement in patient health and function was assessed as secondary objectives.

METHODS

Thirty patients were enrolled at two Canadian sites (16 - Winnipeg, MB; 14 - Halifax, NS) between July 2013 and February 2014. Minimal patient exclusion criteria were applied; active or prior infection, and medical condition precluding surgery. Each patient received a cemented Attune TKR of posterior-stabilized, fixed bearing design. RSA markers were inserted into the tibial bone surrounding the implant during surgery. MBRSA exams were obtained at 6 weeks, 6, 12, and 24 months post-operatively along with patient questionnaires; Oxford-12, EuroQuol, Pain & Satisfaction scales, UCLA activity, and Patient's Knee Implant Performance (PKIP). Double examinations were obtained at the 6-week follow-up to determine clinical precision of the mbRSA system.

RESULTS AND DISCUSSION

After 12 months, the tibial tray migrated an average of 0.02 mm (SD: 0.07 mm) in the superior-inferior direction with an average MTPM of 0.20 mm (SD: 0.10 mm). After 24 months, average migration was virtually unchanged at 0.02 mm (SD: 0.08 mm) and 0.21 mm (SD: 0.12 mm) in the superior-inferior and MTPM directions. Patient outcome scores improved significantly pre- to post-operative with Oxford-12 improving 21 points (SD: 9.0, $p<0.001$), overall health increasing 7.7 points (SD: 15.3, $p<0.001$), a 51-point reduction in pain (SD: 26, $p<0.001$), an increase in UCLA activity scale of 2.2 points (SD: 2.1, $p<0.01$), and increase in PKIP of 8.0 points (SD: 13.1, $p<0.01$)). Further, patient satisfaction for this cohort at 12-months is 91% (SD: 11%).

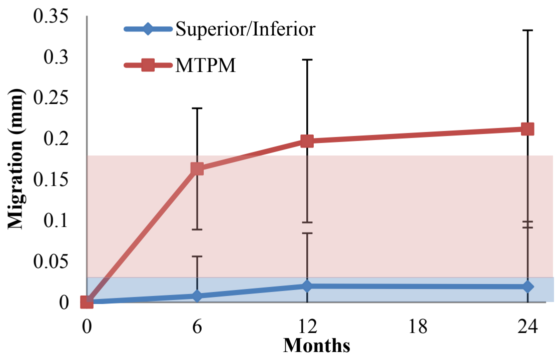

Figure 1: Plot of tibial tray migration. Error bars represent 1 standard deviation. Coloured bands represent the margin of error for each metric based on the calculated precision of the MBRSA system.

CONCLUSIONS

The results of this study demonstrate the tibial baseplate of this knee replacement system is well fixed with migration under previously published thresholds at 12 months for tibial components 'at risk' of long-term loosening [1]. Migration was virtually unchanged between 12 and 24 months further indicating baseplate stability. Patient-reported outcomes show significant improvement in function, pain, activity, and quality of health following the knee replacement procedure.

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   TT & TG have received institutional support in the past from DePuy-Synthes in the form of Fellowship education grants.

KINEMATIC EVALUATION OF THE DEPUY ATTUNE™ PROSTHESIS USING DYNAMIC RSA

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INTRODUCTION

The present work is focused on the Depuy Synthes ATTUNE™ FB PS analyzed using Dynamic RSA. This model has a variable curve radii of the femoral condyles that should guide the flexion movement in a more physiological way. Thus, the end-point is the quantification of femoral translational and rotational patterns during weight-bearing motor tasks, with active muscle contraction.

METHODS

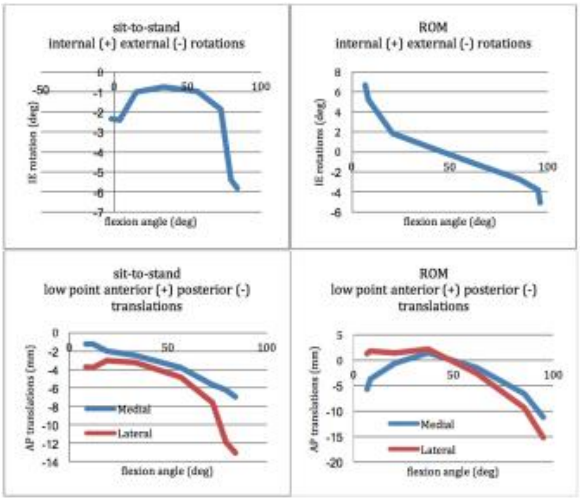
The dynamic RSA used a Bi-STAND DRX (ASSING Group, Rome, Italy) device and the patients were asked to perform 2 motor tasks:

1. Sit-to-Stand: from the sitting position, the patient stands up.
2. Range of motion (ROM): the patient was asked to extend the knee from the maximum flexion to the maximal extension while sitting on the chair.

The kinematic was analyzed using custom dedicated software. The motion parameters were evaluated using the Grood and Suntay [1, 2] decomposition and the Low-point kinematics [3]. The time was normalized in percentage (0% begin, 100% end of the motor tasks). A random cohort of 15 randomly selected patients was operated and evaluated. The mean age of the patients was 73.4 years (95%CI, 65-72). The patients were evaluated using dynamic RSA after 9 month follow up.

RESULTS AND DISCUSSION

The clinical parameters and scores evaluated pre-, intra- and at 9m FU showed an overall increase of the clinical scores KSS-c and KSS-f from "poor", to "excellent" and the VAS scale had a significant reduction. The kinematical data of the examined motor tasks were analyzed and shown in figures 1. The IE rotations show a different behavior at low flexion angles due to the different type of motor task, i.e. close kinematic chain vs open kinematic chain. The Low point translations show similar behaviors. The trends of the two plots is in agreement on what was reported in [3], and show that the screw-home mechanism and the medial pivot are restored as in the physiological knee.



Figures 2: "sit-to-stand" kinematics on the left. "ROM" kinematics on the right.

CONCLUSIONS

The pre- and post- operative clinical scores shows an excellent satisfaction of the patients after 9 month. The data highlight the particular kinematic of the this model of prosthesis.
These results show that the Depuy Synhtes ATTUNE™ prosthesis restore a correct kinematics of the joint, as expected. Further studies will analyze the kinematic of this implant with different motor tasks to highlight possible hidden instabilities and compare the prosthesis kinematic with a healthy knee.

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