

Institution: Anglia Ruskin University
Unit of Assessment: UOA 15 General Engineering
Title of case study: Improved Hip Replacement Fixation Techniques to Increase Implant Longevity
<p>1. Summary of the impact</p> <p>Our research has developed improved hip replacement fixation techniques, which have improved the biomechanical stability of implanted artificial joints. These techniques have been employed by orthopaedic surgeons, for example at Mid-Essex Hospitals Services Trust (MEHT), in primary and revision total hip replacement operations. As a result, the number of patients requiring revision hip surgery due to cup loosening has fallen by 50%. Additionally, these techniques have reduced the recovery time per operation by 3-5 days, which in addition to benefitting the patient have also resulted in an average saving per operation of £1,200.</p>
<p>2. Underpinning research</p> <p>Research has been undertaken since the mid 1990s to address inadequate surgical guidelines on implant fixation in total hip replacement (THR) operations. Our research activities originated with an investigation in the biomechanical integrity of the 'cement-within-cement' reconstructed joint revision technique. It was found that a thin layer of blood and marrow debris at the interface weakened the bond by 80%.¹ This finding raised surgeons' awareness of the need to remove all old cement if the entire interface could not be reliably cleared of blood and marrow fat during revision. This led to the Chelmsford Medical Education and Research Trust (CMERT) providing funding (£145k) between 2008 and 2013 to research the treatment, based on clinical needs, of osteoarthritis and venous ulcers.²</p> <p>Prompted by the wide variation in THR surgical techniques, a survey of practice conducted in 1998 amongst 484 orthopaedic surgeons in the UK revealed wide variations in the number, diameter, depth and locations of anchorage holes drilled in the hip socket, the maintenance or removal of the subchondral bone and the thickness of cement mantle used. With the aim of improving patient recovery and the longevity of the replacement hip, a series of investigations on the effects of these surgical techniques on the long-term stability of THRs was undertaken.</p> <p>Computer simulations and laboratory investigations^{3,4} (2000-2007) revealed that long-term fixation of hip implants could be improved by: i) creating large anchorage holes, perpendicular to the hip socket, with rounded neck and with depth not exceeding diameter, ii) drilling 3 large anchorage holes instead of many smaller ones, and iii) preserving the subchondral bone.</p> <p>To investigate how THR fixation techniques varied with bone sizes and densities, our research (2003-2009) revealed that i) patients with poor bone quality and smaller hip socket need thicker cement mantles and ii) uniform cement mantles result in increased longevity⁵. These results prompted the design of a novel, safe, quick and easy technique, which helps to create uniform cement mantles with the desired thickness. This is difficult to achieve in theatre.</p> <p>To address the common problem of osteonecrosis, caused by heat released from surgical power tools, Mootanah and Zizzo designed and built an intelligent power tool prototype (2006), patented through our University (WO/2007/141578), allowing surgeons to control heat released during operation. We have also worked with A-One Medical BV, a Dutch orthopaedic company, and Rinjvick Hospital (2006) to evaluate the biomechanical performance of the REX cement plug. Results of this collaborative work⁶ enabled the manufacturer to identify and address the weakness of their insertion device.</p> <p>Key researchers are Ingle (Senior Lecturer 1980–2000, Reader 2000 – 2006, Professor of Biomedical Engineering 2006 - 2007); Mootanah (Post-doctoral Research Fellow 2001 – 2006, and Senior Lecturer 2007 - to date); Zizzo (Professor 2003 – 2007, and Head of the Department of Design and Engineering 2004 – 2005).</p>

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On average, 72,000 total hip replacements (THR) are carried out in the UK each year, each costing £7,500 - £13,450. It is estimated that the number of THRs will increase by 40% over a 30-year period due to demographic change alone. Our findings will significantly improve patient prognosis and reduce costs related to the care of these patients.

3. References to the research

1. Li P.L., Ingle P.J., Dowell J.K. (1996). 'Cement-within-cement revision hip arthroplasty: should it be done?', *Journal of Bone & Joint Surgery (British Volume)*, 78 (5): 809-811. Available online: <http://www.bjj.boneandjoint.org.uk/content/78-B/5/809.full.pdf+html>

2. Five grants from the Chelmsford Medical Education & Research Trust from February 2008 to September 2013 each awarded to Dr. Raj Mootanah as follows :-

Title: In vitro investigations of the effects of different surgical procedures for the repair of meniscal tear on knee contact pressures

Period of the grant : September 2011 – August 2012

Value of the grant: £20k

Title: In vitro investigations of the effects of different surgical procedures for the repair of meniscal tear on knee contact pressures – Part 2

Period of the grant (with dates): September 2013 – August 2015

Value of the grant: £34.8k

Title: The prototype manufacture of an intermittent pneumatic graduated compression boot for the treatment of venous ulcers

Period of the grant (with dates): February 2008 – July 2009

Value of the grant: £19.95k

Title: The intermittent pneumatic graduated compression boot for the treatment of venous ulcers - Part II

Period of the grant (with dates): February 2012 – January 2015

Value of the grant: £35.8k

Title: A less invasive approach to the treatment of osteoarthritis – High Tibial Osteotomy

Period of the grant (with dates): September 2010 – August 2012

Value of the grant: £35k

3. Mootanah R., Ingle P., Dowell J.K, Cheah K., Shelton J.C., (2000) 'Fixation of the acetabular cup in cemented total hip replacement: improving the anchorage hole profile using finite element method', *Technology and Healthcare*, 8 (6): 343-356. Available on demand from the HEI.

4. Mootanah R., Dowell J.K., Cheah K., Ingle P., Shelton J.C., (2007) 'Configuration of anchorage holes affects fixation of the acetabular component in cemented total hip replacement – a finite element study', *Computer Methods in Biomechanical and Biomedical Engineering*, 10 (6): 439-445. Available via DOI: 10.1080/10255840701633943

5. Lamvohee J.M., Mootanah R., Ingle P., Cheah K., Dowell J.K., (2009) 'Stresses in cement mantles of hip replacements: Effect of femoral implant sizes, body mass index and bone quality', *Computer Methods in Biomechanical and Biomedical Engineering*, 12 (5): 501-510. Available in REF2

6. Kroon M., Visser C.J.P., Mootanah R., Schuttevaer H., Brand R (2006), 'Performance of three gelatine-based resorbable cement plugs: Results of an in vitro study on 15 synthetic femurs and a prospective randomized in vivo study on 103 patients'. *Acta Orthopaedica*, 77 (6); 893-898. Available via DOI: 10.1080/17453670610013187

4. Details of the impact

The impact of this research has changed the way orthopaedic surgeons carry out THRs. Fewer and larger anchorage holes are drilled perpendicularly to the hip socket to reduce stress risers and

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implant failure. The subchondral bone is preserved to maintain good load distribution in the hip socket and cement mantle thickness is selected according to patient bone quality and size. Cement-to-cement interface is thoroughly cleaned during revision surgery to maintain mechanical integrity.

Our research activities are clinically led; we work closely with orthopaedic clinicians from MEHT, Broomfield Hospital (2008-2013) and Ramsay Springfield Hospital (2008-2013), to improve THR surgical fixation techniques to increase implant longevity and to delay or avoid the need for revision surgery.

We have raised orthopaedic surgeons' awareness of the wide variations in surgical fixation techniques and the importance of correct implant fixation techniques to increase biomechanical stability through research dissemination to major stakeholders and at strategic meetings, including:

- i) major international conferences, regularly attended by orthopaedic surgeons and companies, (the 18th European Orthopaedic Research Society, July 2010, Davos, >300 delegates; the 22nd International Society of Biomechanics; July 2009, Cape Town, 595 delegates; the 22nd International Society of Technology in Arthroplasty, October 2009, Hawaii, 600 delegates; MERG-organised mini-symposium on surgical fixation techniques at the 8th Computer Methods in Biomechanics and Biomedical Engineering Conference - February 2008, Porto, >400 delegates);
- ii) the East of England Orthopaedic Research Meetings, (The Black Notley Conferences - March 2013 and June 2012, and the Denis Dunn Day - June 2008, >100 delegates, each)
- iii) journal publications: (Technology and Healthcare, 2008 16(1):19-30; Computer Methods in Biomechanics and Biomedical Engineering, 2009 12(5):501-510);
- iv) medical companies to integrate new knowledge in their products (invited speaker at ERBI 11th Cambridge BioPartnering Exchange, June 2009, attended by over 800 delegates; London Technology Network conference in March 2009, attended by over 200 delegates; the joint Anglia Ruskin University Medical Engineering / MediTech / HealthTech and Medicines Knowledge Transfer Network Conference in June 2011, attended by 65 delegates);
- v) patients, their carers and the wider community, who are the direct beneficiaries (the Broomfield Hospital Hip Day, June 2008, attended by over 200 THR patients / carers);
- vi) funding bodies – presentation of CMERT-funded research outputs at annual progress review meetings to the CMERT committee from 2009 to 2013).

Our research has helped surgeons make informed decision on treatment methods. For example, a Consultant Orthopaedic Surgeon at MEHT (Broomfield Hospital) testified: *"...I have used the techniques that were seen to be effective from the research you did concerning the shape, number of key holes and cement mantle thickness in cemented total hip replacements since 2000, with excellent results. The clinical importance is the success of the operation and the reduction in the number of patients requiring revision hip surgery for aseptic loosening of the acetabular cup, thus saving the NHS costly revision surgery. I think that the use of these techniques would reduce the need for revision hip surgery by 50%. This would be 8% loosening over 10 years prior to introduction, to 2-4% since the introduction of improved techniques."*

A Consultant Orthopaedic Surgeon at Broomfield Hospital has implemented these surgical fixation techniques on 35 THRs annually from 2000 to 2010, when he focused on spine surgery. During this time, he had been training 2 surgeons annually to use our recommended surgical techniques. He believes that our recommended surgical fixation technique has resulted in a reduced length of stay in hospital by 4 days for each THR operation and reduced patient recovery time. THR patient satisfaction remains high at 98%. Savings associated with length of stay in hospital alone (£300/day) are estimated to be £696,600 between 2008-2013. Further savings are associated with the lower unit cost of a cemented polyurethane cup (£235-£389) compared to those of a non-cemented ceramic cup (£1,663) and a non-cemented polymer cup (£1,351), resulting in a saving of £1,000-£1,300 per operation.

The trend of an increasing number of continuing impacts emerging from our work on THR is demonstrated by the following:

- Broomfield Hospital has recently been highly rated nationally for total hip replacements.

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According to new data from the Department of Health patients who have hip replacements at Broomfield Hospital have the best outcomes in the country. According to analysis by the King's fund thinktank, Broomfield Hospital scored highest in patient-recorded outcome measures for hip replacements among over 200 English NHS hospitals Mid Essex Hospitals scored very high in Hip Fracture Care, according to the 2013 National Hip Fracture Database Report, which covers 61,508 hip fracture cases among 180 UK hospitals.

- Continual stream of external income from the CMERT (five awards since 2008, total of £145,650), as a result of their confidence in our research –detailed in Section 3;
- Successful long-term collaborations with prestigious institutions that resulted in high-quality research outcomes are: i) the Hospital for Special Surgery – top-ranked orthopaedic hospital in the US, rated by the US news and World, and ii) Boston and Harvard Universities, to translate our research skills to the conservative treatment of the lower limb. Two prestigious international awards resulted from this novel approach to identify and treat early-stage knee osteoarthritis: i) best Orthopaedic Research Society knee poster at the 2013 American Academy of Orthopaedic Surgeons meeting, which attracts over 25k delegates, and ii) the 2012 Mimics Innovations Award.
- Successful collaboration with scientists from Micro and Nanotechnology Centre of the Science and Technology Facilities Council, the Electrospinning Company Ltd and Symmetry Medical on novel biological nanocoating technology on implants. Our complementary expertise led to a 2008 Medical Futures Innovation Award in the Orthopaedics Category.

5. Sources to corroborate the impact

1. Implementation of THR improved surgical fixation techniques: Consultant Orthopaedic Surgeon, FRCS, at Mid-Essex Hospital Services Trust, Broomfield Hospital.MFIA award: <http://www.nanowerk.com/news/newsid=8643.php>
2. The 2013 Orthopaedic Research Society conference proceedings, page 81, stating: 'The following posters have been chosen as the ORS Best Posters and will be displayed at the American Academy of Orthopaedic Surgeons (AAOS) meeting in March. The ORS Best Posters will have a ribbon on their poster.' This also demonstrates our strong collaboration with the Hospital for Special Surgery and the University of Boston.
3. MIMICS Innovation Award: <http://biomedical.materialise.com/mimics-innovation-awards-previous-winners#2012>. This also demonstrates our strong collaboration with the Hospital for Special Surgery.
4. The Unit collaboration with the University of Harvard is shown by the recent conference presentation: 1. Mootanah, R., Hillstrom, H.J., Dufour, A.B. & Hannan, M. 2013, "Prevalence of foot, skin and nail disorders among women wearing high-heeled shoes: the Framingham Foot Study", XXIV Congress of the International Society of Biomechanics , ed. ISB2013, ISB2013, Natal, Brazil, August 4-9.
5. Research funding from the Hospital for Special Surgery in 2013 (\$60,000, of which \$37k to us): Modelling and simulation of a novel surgical reconstruction technique for the 1st metatarsophalangeal joint. This also demonstrates our strong collaboration with the Hospital for Special Surgery.
6. Funding from the British Orthopaedic Foot and Ankle Society (£5k): The Effect of Different First Metatarsal Lengths on Stress Distribution in the First Metatarsophalangeal Joint: A Finite Element Study.
7. Broomfield Hospital highly rated nationally for total hip replacements for outcomes and best patient-recorded outcome measures: i) <http://www.theguardian.com/society/2010/nov/17/nhs-proms-patient-care>; ii) <http://www.meht.nhs.uk/news/press-releases-archive/press-releases-archive-2010/press-releases-november-2010/18th-november-2010-tae-kwon-do-champion-is-proof-that-broomfield-is-best-in-the-uk-for-hips/>; iii) <http://www.meht.nhs.uk/news/press-releases-2013/2nd-october-2013-mid-essex-tops-in-hip-fracture-care>