(ME042) Reducing the failure rate of hip replacements and the associated costs to the NHS

School of Engineering & Zimmer Biomet Healthcare UK Ltd

Supervisory Team

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Overview

Hip replacement surgery has been hailed as the ‘operation of the 20th century’ [1]. However, 5% of patients will have their new replacement hip fail prematurely within 10 years and this rate continues to rise with time of implantation resulting in thousands of revision operations. Our research goal is to make a replacement hip last for the full lifetime of every patient. However, considering the vast numbers of hip replacement operations the NHS undertakes (~100,000 per year in the UK with nearly 1 million performed worldwide in total) even a modest improvement of longevity would benefit thousands of patients every year, and save a significant proportion of the £50 million spent on failed hip implants by the NHS per year.

The hip replacement operation consists of removing the diseased hip bones and cartilage and replacing these with metal, ceramic and polyethylene components. The polyethylene cup is cemented into the pelvis, pressed into the cement by the surgeon and left to set in position. Recent work by the Freeman Hospital, Newcastle has highlighted a key problem of loosening at the hip cup cement layer and the bone beneath [2]. Working with Zimmer Biomet, our aim is longer-lasting replacement hip joints, reduced costs for the NHS, and improved outcomes for patients, plus valuable knowledge transfer for all orthopaedic stakeholders, as well as Zimmer Biomet.

The challenge facing us is how do we reduce the known failure of these implants significantly below 5% and as close to 0% as possible? Importantly, failures are not typically due to wear of the bearing surfaces anymore; in fact, it is now commonly related to loosening of the cemented cup in the bone itself.
Understanding why this happens is not well understood. Pilot data acquired by the lead author has shown that the polymerising cement under pressure behind the cup does not behave like a viscous fluid and in fact behaves much more like either a fluid suspension of particles, or a heavily visco-elastic material. This means that the cement pressure (and hence the amount of penetration of the cement into the porous bone below) is lower at the equatorial part of the implanted hip cup than at the bottom. This phenomenon is supported by the evidence emerging in the literature of ‘lucent lines’ at the edges of cups on x-rays [2], which is a sign of de-bonding or cracking failure precisely at the area where cement pressurisation is weakest. In addition, the generation of wear particles during day-to-day living when the new artificial hip starts to wear also accelerates de-bonding of the cemented interface, as fluid containing debris is known to exacerbate loosening [3].

Zimmer Biomet have an interest in developing ‘flanged hips’ that are designed to maintain pressure more effectively and evenly around the whole of the cup’s cement mantle. The key novel focus for this PhD will be to understand what fundamental parameters govern cement pressure and how we can re-design implants and surgical methods in order to drastically reduce the existing probability of premature cracking and loosening due to insufficient cement interdigitation (the degree of ingress of cement into the voids in the bone of the pelvis). Previous work on failing hips at Newcastle lead to a REF 2014 impact statement [see Annex I for details].

Our objectives: 1) We will develop novel testing methodologies which will allow us to understand what surgical and orthopaedic design parameters most influence cement pressure, interdigitation and why; 2) work with Zimmer Biomet on new next-generation design iterations of hip implants with improved cement mantle longevity and consequently better outcomes for patients; 3) investigate how surgical methods can be improved in order to assist in better control of cement pressurisation of hip cups, thereby potentially reducing failure rates and NHS costs for all types of hip replacements.

Methodology
The lead author has previously been successful in obtaining funding for a cyclic hip simulator machine which would be used extensively in this project. Firstly, the PhD student will design bespoke fixtures for a cyclic loading simulator in order to run fatigue testing experiments, after which various techniques will be used to look for clues as to how failure initiates. Secondly, using a micro-computer controlled and instrumented compression rig, already developed by the lead author, the student will improve this so that pressure distribution can be measured for a range of clinical circumstances and designs of implant. Thirdly, this data will help validate an FEA and/or CFD model, which, would be a useful tool in order to more rapidly assess design iterations of hips, and changes in surgical methods, e.g. changing the load or cement viscosity used when implanting hips. All the methodologies developed and the results will be published so that all stakeholders in the orthopaedic community will benefit.

Timeline
Year 1: Background to clinical drivers of failure; planning of realistic milestones; cyclic fatigue tests
Year 2 Lab-based cement pressure and flow investigations supporting FEA/CFD validation; placement at Zimmer Biomet; results published
Year 3: Cyclical fatigue tests of new designs, variations on surgical techniques investigated; publication
Year 4: (six months) Thesis writing-up & publication

Training & Skills
Weekly meetings will take place with the Newcastle supervisors and monthly Skype meetings with the industry partner in between visits. Regular attendance at Newcastle Bioengineering Group meetings and UK and international conferences will develop and broaden the student’s professional networks and help develop research ideas further. A personal training programme will be planned at the start of their PhD and, combined with a portfolio of professional development evidence, will help to support a CEng chartership application with the IMechE at the end.

References & Further Reading

Further Information
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