QUB - Mechanical and Aerospace Engineering PhD Project 2019-2020

Title: Biomechanical Evaluation of Reality-Based Navigation in Total Hip Replacement

Project description:

While total hip replacement is a very successful orthopaedic procedure, there continues to be considerable unwanted surgical variation with regard to restoration of femoral head centre (FHC; **Figure 1**). Failure to restore FHC can result in dislocation, increased wear, and leg length discrepancy. The most common errors are making the femoral neck cut too high and using a femoral stem of inappropriate offset. This variation can be reduced by using navigation, e.g. sophisticated patient-specific instrumentation (reality-based) and/or intra-operative medical imaging (image-based). All these options can be expensive, plus intra-operative imaging is difficult to use when the patient is in *lateral decubitus* (lying on their side, which is currently the most common operative position).

Professor David Beverland (Musgrave Park Hospital) has been working on the development of a simplified surgical navigation device, which allows the surgeon to set the femoral neck resection after locating FHC. This design has now been adopted by a leading orthopaedic company who have patented it and are developing it for use in the orthopaedic theatre. One of the critical points is being able to check femoral offset during surgery.

Other work by Queen's University Belfast and Musgrave Park Hospital has investigated the distortion in apparent proximal femoral geometry that occurs as a result of flexion in combination with external rotation of the femur (**Figure 2**).[1] Such radiographic distortion is a particular barrier to pre-operative surgical planning and post-operative assessment as it affects estimation of FHC. Improving estimates of FHC from radiographic data by accounting for such distortion is therefore an important step towards improving both planning and post-operative analysis of any new surgical interventions aimed at improving FHC restoration.

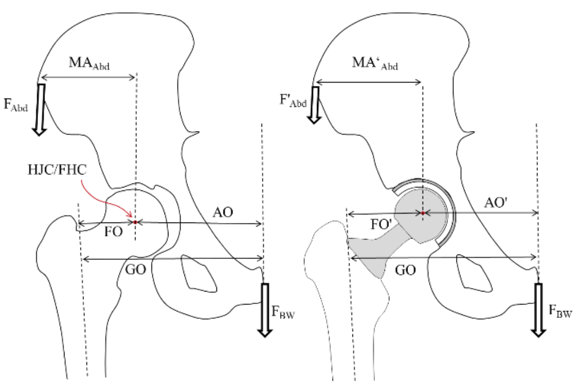

Figure 1: Illustration of native vs post-operative joint geometry.

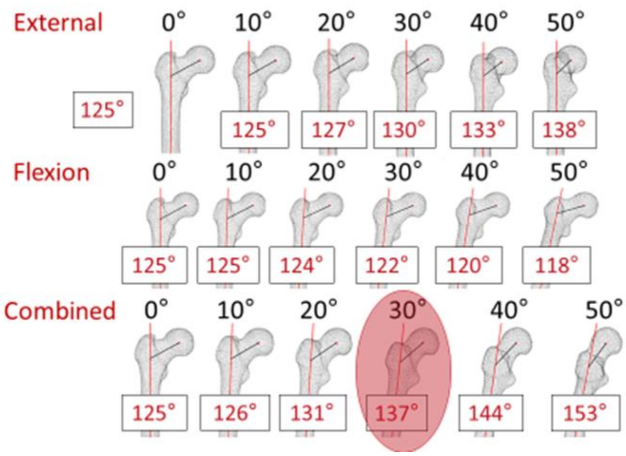

Figure 2: Variable appearance of femurs for possible orientations occurring during x-ray acquisition. Highlighted case illustrates relatively common case for osteoarthritic patients.

Aims and Objectives:

The overall aim of this project is to develop a biomechanical analysis framework that can assess the potential of reality-based navigation techniques for restoring FHC, using a recently developed navigation device as an exemplar application. Three specific research questions will be used to pursue this aim:

1. Can restoration of FHC, and thus femoral offset, be controlled using the new device?
2. To what extent would the new device be better at restoring FHC than current conventional techniques?
3. What is the biomechanical impact of levels of FHC restoration achieved with the new device compared to conventional radiograph-based planning?

Methodology:

Four studies are proposed that aim to:

1. Use a large computed tomography (CT) dataset to establish the likely variation to be expected from current operative planning and the proposed device-based technique to restore FHC. Methods

involved will require medical image manipulation and analysis (3D and 2D), and 3D-to-2D projection to simulate radiographs.
2. Develop a tool to correct offset measurements for non-neutral femur orientation in AP X-rays using statistical shape modelling techniques in conjunction with methods developed in Study 1.
3. Estimate the deviation between restored and natural FHC in two cohorts of hip replacement patients (radiograph-based vs reality-based planning), using the tools developed in Studies 1 and 2.
4. Establish whether deviation between restored and natural femoral head centre has any measurable impact on either biomechanical or clinical outcomes using musculoskeletal biomechanics simulation (**Figures 3 and 4**).

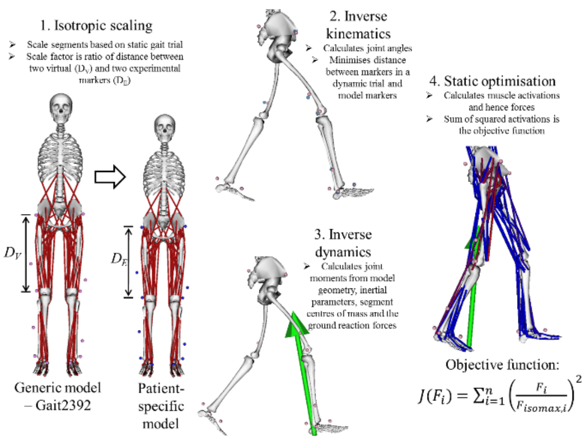

Figure 3: Typical musculoskeletal biomechanics modelling workflow

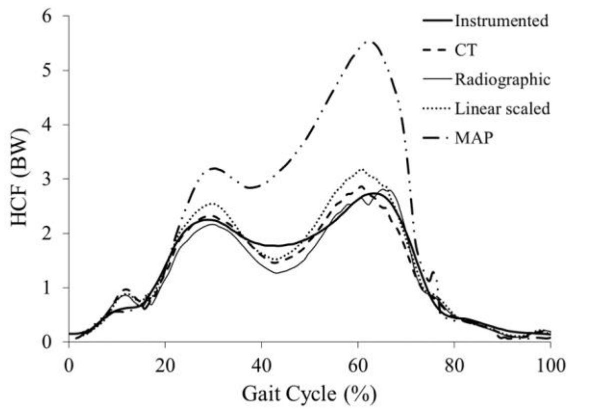

Figure 4: Example of how femoral offset variation (due to different techniques to estimate it) impacts hip contact force in a hip replacement patient.

References

1. Effect of combined flexion and external rotation on measurements of the proximal femur from anteroposterior pelvic radiographs. O'Connor JD, Rutherford M, Hill JC, Beverland DE, Dunne NJ, Lennon AB. Orthop Traumatol Surg Res. 2018 Jun;104(4):449-454.

Key skills required for the post:

- A minimum degree of 2:1 (or equivalent) in mechanical engineering, biomedical engineering, or another relevant discipline.
- This challenging and interesting project requires computational, scientific, and interdisciplinary communication skills. Applicants should have a keen interest in medical image analysis, 3D modelling, and numerical modelling applied to biomechanics.

Key transferable skills that will be developed during the PhD:

Transferable skills that will be developed during the PhD are i) scientific computing, ii) communicating to a multidisciplinary audience, iii) time management, and iv) leadership skills.

Lead supervisor:	Dr Alex Lennon (a.lennon@qub.ac.uk)
Other supervisor(s):	Prof. Nicholas Dunne Prof. David Beverland
Guaranteed stipend:	The studentship covers fees (approx. £4,327/year for UK/EU students eligible for UK home fees) and includes a tax-free income of £14,925 /year. There is also the opportunity to undertake teaching and demonstration duties within the School to earn additional income (see below).
Conditional top-up available:	n/a

PhD students in the School have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to in excess of £2,400 per year.

Queens University Belfast is a diverse and international institution which is strongly committed to equality and diversity, and to selection on merit. Currently women are under-represented in research positions in the School and accordingly applications from women are particularly welcome.