INTRODUCTION:

Hip resurfacing is an attractive treatment option for young and active patients; offering greater bone conservation and allowing more natural load transfer than total hip replacements [1]. However, resurfacing procedures have been associated with significant complications including femoral neck fracture, osteonecrosis within the femoral head, neck thinning and aseptic loosening [1,2,3].

Finite Element (FE) studies have been carried out to investigate the changes in load transfer through the proximal femur following femoral resurfacing. These have indicated a propensity to stress shielding in the femoral head, which may lead to bone resorption, and an increase in strain around the implant rim and in the femoral neck [4,5], potentially contributing to failure mechanisms such as neck fracture and implant loosening.

It has been observed that women suffer a higher complication rate and have shorter implant survival than men [2,6], and that larger implant sizes have greater survivorship than small [3,7]. This study utilised a statistical model to generate a population of FE femur models and automated a computational femoral resurfacing analysis. The strain changes produced by the procedure were compared between examples with large and small implant sizes. It was hoped that by examining a population of femurs, as opposed to a single or small bone set as in previous studies, the influence of implant size would be seen.

METHODS:

260 FE ready femur models, each with unique geometry and material properties, were generated by sampling a statistical model built from 46 Computer Tomography scans. A fully automated methodology was scripted to perform and link all stages of the analysis. Each femur was measured to assess the size and alignment required for the resurfacing component. One of 12 femoral implants was then chosen from a set ranging in size from 38mm dia. to 60mm dia. in 2mm increments. HyperMesh\textsuperscript{TM} (Altair Engineering Inc., USA) was used to perform Boolean operations, which replicated surgical cuts, and to generate a 3mm thick layer simulating bone interdigitated with bone cement. Ansys ICEM\textsuperscript{TM} (Ansys Inc., Canonsburg, PA) was used to create a tetrahedral mesh of the bone (0.5-1.5mm proximal, 2-4mm distal), cement (0.75-1.5mm) and implant (0.75-1.5mm) with nodal correspondence across their shared boundaries. The elemental material properties of the cut bone were then reassigned from the original femur mesh (Figure 1).

Each femur was run in intact and implanted configurations; with identical subject specific load cases applied simulating level gait [8]. The load was defined by estimating patient height from femur length, randomly assigning BMI from a distribution curve, leading to a body weight value. A static, linear elastic FE analysis was then run and the resulting elemental strain extracted (Figure 1).

In order to compare the strain distributions between the intact and implanted models, each bone was sectioned into 16 regions of interest along the femoral neck axis, defined when aligning the implant (Figure 2). The strain results from the intact instances were assigned to the implanted bone, thus ensuring identical bone volumes were compared.

RESULTS:

Of the generated population of 260 femurs, detailed comparison was performed on 19 which required a small implant, dia. 46.5mm, and a further 19 which required a large implant, dia. 58.5mm. The strain results of these two groups both indicated strain shielding in the femoral head, particularly the most superior sections 1 and 9. An increase in strain in the femoral neck was common to both, however this was small and confined to section 3 in the larger implant (mean +5.4%) and greater and present in sections 3 and 11 in the smaller (mean +18.8% and +8.5%). Statistically significant areas of difference are shown in figure 2. Of these, sections 1 and 11 show the largest separation between the implant sizes, indicating that the smaller implant sees greater strain shielding in the proximal femoral head and greater increase in strain in the superior femoral neck.

DISCUSSION:

A population of 260 femurs was generated automatically, of which 19 required a small implant (dia.46.5mm) and 19 required a large implant (dia.58.5mm). Comparisons between the intact and implant configurations of these models allowed the influence of implant size on load transfer to be investigate over a set of femurs, which has previously not be possible without major manual intervention.

The overall trends of the analysis agrees with previous computational and clinical studies, suggesting strain shielding of the proximal femoral head and increases in strain in the femoral neck [1,2,3,4,5]. Statistically significant differences were also seen between large and small implants, where the latter show greater strain shielding in the femoral head and great strain increase in the neck. This finding corroborates previous observations that smaller implants perform worse than larger implants [2,3,7] and provides a possible insight into how the generally poorer outcomes for women could be partly explained by their smaller size [3].

REFERENCES:


ACKNOWLEDGEMENTS: DePuy UK and Technology Strategy Board, UK.