# A MULTIPLE MATERIAL PARAMETER FINITE ELEMENT MODEL OF HIP RESURFACING ARTHROPLASTY

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## INTRODUCTION

Hip resurfacing arthroplasty (HRA) is increasingly carried out as an alternative to total hip arthroplasty (THA) in young, active patients. The primary indication for this surgery is osteoarthritis. It is favoured over THA as it preserves bone stock and it is claimed not to cause stress shielding. However, fractures of the femoral neck result in short term failure of the procedure in approximately 2% of patients [1]. Previous finite element (FE) analyses have employed over-simplified material parameters to define the femoral bone and non-physiological loading conditions [2,3]. Furthermore, it is unclear from the literature whether the surface interaction between the implant and bone cement is a 'sticking/sliding' contact best represented using a Coulomb friction model or whether it is a 'glued' contact. In this study an experimentally validated FE model of a cadaveric femur pre- and post- HRA surgery was analysed to determine the change in mechanics. This model included physiological loading conditions and more accurate multiple material parameters represented nonhomogeneous bone distribution in the femur.

## METHODS

Material properties were assigned to the femoral bone using the data from a detailed CT of a cadaveric femur [4]. Intact and implanted FE models were validated using experimentally measured strains compared with model calculated strains. The surface interaction between the retro-surface of the implant and the underlying bone cement was represented using either a Coulomb friction model ($\mu$=0.3) or as rigidly bonded ($\mu$=infinity). A physiological load case representing the muscle and hip contact forces at an instant 10% through the level walking gait cycle was applied to the intact and implanted models. Von Mises stresses were compared in three cross-sections through the neck of the femur (Figure 1a) and in the femoral head. To determine the potential for femoral bone fracture under this physiological loading condition, a risk of fracture (RF) scalar was calculated as the ratio between the Von Mises stress and the ultimate strength of bone. A value greater than one indicated a potential failure.

## RESULTS AND DISCUSSION

It was found that the use of 381 separate material parameters to define the femoral bone was optimum. The correlation between the experimental and calculated strain values for the two material model had $R^2$=0.87, while in the model incorporating 381 materials $R^2$ was 0.92. Von Mises stress in the femoral head was 0.8 to 3.2% higher when the implant and bone cement were rigidly bonded; however, Von Mises stress in the femoral neck was the same in both the implanted models. Therefore, only results for the Coulomb friction model are considered. For this physiological load case the change in maximum Von Mises stress after resurfacing, expressed as a percentage of the reported ultimate compressive strength of cortical bone (193MPa) ranged from -1.8% to 1.0% (Figure 1b). Of the 47,984 elements in the implanted model, 72 had an RF value greater than 1. As these elements were remote from one another and it was unlikely that localized volumes of bone would be sites of fracture, the fracture risk post-HRA surgery was assessed to be low.

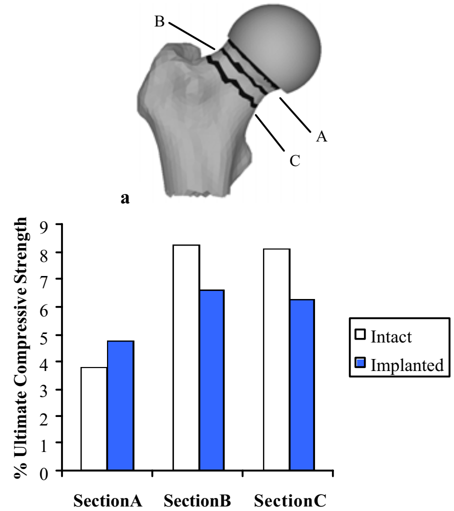


**Figure 1**: **a.** Cross-sections in the femoral neck; **b.** Peak Von Mises stress in femoral neck as a percentage of ultimate compressive strength

## CONCLUSIONS

A multiple material property model more closely simulates real bone mechanical properties than a 2 material model. This is the first fully validated FE model of a femur implanted with an HRA. These results indicate that the geometry and direction of loading on the implant result in implant-cement interface stresses that are transmitted to the underlying bone as if these two materials were rigidly bonded. Analysis of the intact and implanted FE models under physiological loading conditions appears to support the claims that HRA does not result in stress shielding in the femoral neck. Furthermore, the calculated bone stress in the femoral neck was not sufficient to be a potential cause of fracture.

## REFERENCES

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