

THE RESPONSE OF THE ACETABULUM DURING LOADING: A FINITE ELEMENT SENSITIVITY STUDY

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INTRODUCTION

Finite element analysis is fast becoming a frequent tool employed in the study of implant biomechanics. The benefits it offers are plenty, not only in terms of time and cost reduction, but ethically in the reduction of *in vivo* studies concerning implants that could be rejected at an earlier stage. Coupled with these benefits is a potential high risk of misuse. Any results provided with finite element analysis must come with a thorough understanding of how they relate to the *in vivo* situation trying to be replicated. This is an understandably difficult task. Validation and sensitivity studies are key in developing this understanding.

This paper details a set of sensitivity studies focussing on the acetabulum as an area of interest. Future work will involve the study of stresses and radial deformation within acetabular cup implants. Sensitivity studies were thus performed with respect to the output parameters of Von Mises failure stress and radial deformation. Initial sensitivity studies were performed on the natural acetabulum, without implant.

METHODS

A protocol was developed based on contemporary finite element studies [1]. CT-data for fourteen full pelvises was segmented and, where appropriate for the study, assigned with material properties based on Hounsfield units [2]. The hemi-pelvis supports at the pubic symphysis and sacroiliac joints were modelled as rigidly fixed in space. The maximum occurring hip joint reaction force during normal gait [3] was applied through a spherical femoral head to each acetabulum in the finite element program and the relevant results extracted and processed.

The sensitivity of Von Mises stress and acetabular radial deformation to a range of input variables was measured. The input variables were acetabular geometry, material property assignment and boundary conditions.

Geometry: Acetabular geometry was described using five key geometric variables whose statistical variation over the standard population was taken from a range of literature. 625 model variations were produced and static loading simulated. Linear regression analysis was performed to highlight the most critical geometric parameters.

Material properties: Material properties were assigned in a variety of three ways on seven different acetabulae. The assignments were: homogeneously, with a 0.9mm cortical layer; heterogeneously, with two different formulas relating apparent density to stiffness [2,4]. Static loading was simulated for 21 models.

Boundary conditions: The following boundary conditions were applied: baseline (sacroiliac and pubic symphysis fixed in space - this was used in all simulations above) and a whole pelvis constrained model in which the L5S1 joint was fixed and the sacroiliac and pubic symphysis joints were described

in a range of different ways, as follows. A single model was produced in which ligament and fibrocartilage material properties were taken from a range of published *in vitro* experimental data [5,6]. Two further models comparing differing ligament stiffness values were created; as well as three models comparing fibrocartilage stiffness.

RESULTS AND DISCUSSION

Contour plots of Von Mises stress and radial deformation were produced for each model. The sensitivity of these two parameters to the variation of the chosen inputs was measured in two ways. The peak stress and peak radial deformation was used as a quantitative comparison; a qualitative metric was devised for comparison between whole acetabular contour plots. Figure 1 shows a quantitative sensitivity comparison and demonstrates that the acetabular stress is highly sensitive to material property assignments and radial deformation to the boundary conditions used at the pubic symphysis and sacroiliac supporting joints.

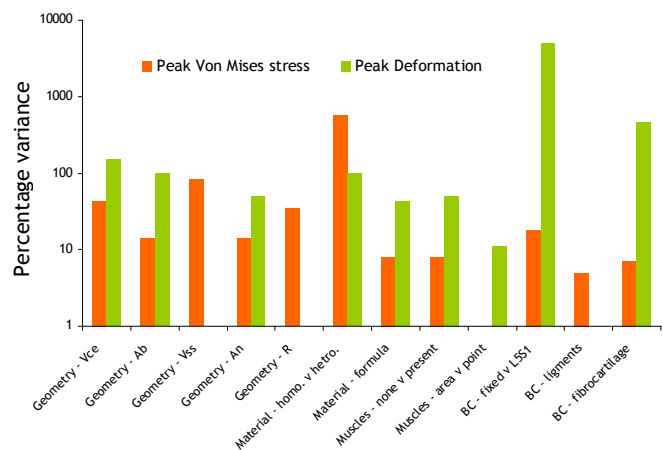


Figure 1: Peak Von Mises stress and radial deformation sensitivity to a range of input variables

CONCLUSIONS

These sensitivity studies show that consideration of potential variance of material property assignment and acetabular geometry is of primary importance if Von Mises stress is sought to be understood; and consideration of acetabular geometry and joint boundary conditions is of high importance if acetabular radial deformation is a required output.

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