VALIDATING FINITE ELEMENT MODELS OF PERIPROSTHETIC FEMORAL FRACTURES TREATED WITH LONG STEM REVISION USING EXPERIMENTAL RESULTS

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Introduction

Clinical failures of fixations for periprosthetic femoral fractures (PFF) suggest that improved surgical recommendations are required [Erhardt, 2008]. A common treatment when the original stem is loose is a longer stem which bridges the fracture site. Computational modelling has the potential to investigate a wide range of fracture and fixation configurations and optimise treatment however these models must first be validated. This study's aim was to develop validated finite element (FE) models suitable for testing the biomechanical effect of factors such as fracture height, angle and type and patient bone quality.

Methods

Six synthetic Sawbone femurs (4th gen, Sawbones, Pacific Research Laboratories Inc., Sweden) were fractured transversely and fixed using a cemented long revision stem prosthesis (Exeter V40 Cemented Hip Long Tapered Stem, Stryker, Switzerland). The specimens were loaded in axial compression to 500N at 0°, 10° and 20° of adduction in the frontal plane while vertical in the sagittal plane with and without 8° of internal rotation. Construct stiffness was measured for each specimen. One specimen was also strain gauged along the longitudinal axis of the diaphysis.

The FE analysis software Abaqus (v6.10, Dassault Systèmes, USA) was used to construct and solve the models based on the experimental specimens. Following convergence testing, the models were meshed with approximately 1 million quadratic tetrahedral elements. All experimental loading conditions were represented. The baseline FE fracture site was filled with cement to match the experiments (Case A), a sensitivity study considered the effect of a 1mm fracture gap (Case B) and a cement free perfectly reduced fracture (Case C).

Results

The FE and experimental models were most stiff at 10° of adduction. The pattern of stiffness change due to loading angle predicted from the FE matched the experimental results well. The sensitivity of stiffness due to loading angle was not replicated however, with the stiffness ranging from 1.37-3.45kN/mm and 4.76-4.98kN/mm for experiment and FE respectively. Medial strain at 10° is given in Figure 1. Strain around the fracture showed good agreement, however values close to the FE models boundary conditions did not closely match the experiment.

Both Case B and C resulted in a significant reduction in stiffness, with Case B also leading to strain reductions around the fracture site.

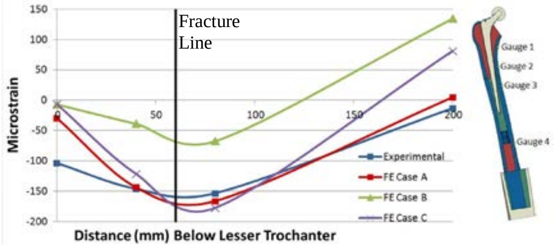

Figure 1 : Medial strain comparison at 10°. Gauge locations given on FE model cross-section.

Discussion

Experimental and FE agreement for strain around the fracture suggest that the bending mode in this key region is being well represented and that results from this area can be used to characterise fixation performance and failure. The effect of the boundary conditions on the strain pattern suggest that further work will be required to consider factors such as proximal stress shielding.

The results were most representative at the more anatomically neutral 10° case so future work will focus here. The overestimation of stiffness by the FE model can be in part attributed to perfectly rigid tie constraints and boundary conditions and the lack of material imperfections. The model proved sensitive enough to fracture configuration to display noticeable biomechanical changes and can now be used to study different clinical factors.

References

Erhardt *et al*, Arch Orthop Trauma Surg, 128:409-416, 2008.