Fracture Simulation of Femoral Bone using Finite Element Method

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I. INTRODUCTION

The mechanical performance of bone is influenced by its ability to withstand load and maintain its structural integrity [1-2]. Despite advances in fracture mechanics, the correlation between the nature of the load applied and the fracture pattern produced is not clear [3]. Moreover, bone fails as a brittle material under high strain rate but behaves as a ductile material at low strain rate [4], which should have an effect on the fracture morphology produced. Therefore, this short communication will illustrate a technique to simulate various fracture processes using finite element analysis.

II. METHODS

Computational Modeling

Finite element models were constructed from magnetic resonance (MR) images of a healthy subject. Physiological boundary conditions adapted from [5] were implemented to model case histories. Fully constrained boundary conditions were also considered for comparison. Bone tissue was assigned transversely isotropic material properties exhibiting plasticity. External loads of varying directions and magnitudes were applied and the model was solved non-linearly. Failure was considered through a damage law coupled with asymmetric yielding of the form:

$$D = 0; \alpha_{eq} \leq 0,\ D = D_c \alpha^n{}_{eq}; \alpha_0 < \alpha_{eq} < \alpha_f,\ D = D_c; \alpha_{eq} > \alpha_f$$

where α, D_c, n and α_f are the failure criteria, the critical damage at fracture, the damage exponent and the critical value at fracture. Visualization of the fracture is achieved by the removal of failed elements.

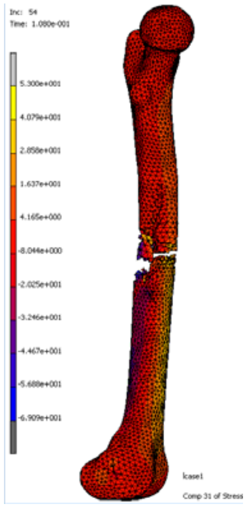

Figure 1: Spiral fracture produced from torsional load

III. INITIAL FINDINGS

The model is able to simulate the fracture pattern produced on impact from crack initiation until the bone is completely fractured (Figure 1). Various fracture patterns, including spiral and transverse fractures, were observed depending on the nature of the loads applied. The stress-strain curve obtained also showed good agreement with literature results.

IV. DISCUSSION

The model was able to simulate the fracture process based on different case histories. In addition, the model's ability to capture post-yield behaviour of the bone and display a stress-strain curve similar to that in literature illustrate its ability to be used as a predictive model to determine the cause of fracture. This model could potentially be checked against radiographic images of other case histories in future to establish their failure mode.

V. REFERENCES

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