Failure in the Proximal Femur in Simulated Sideways Fall Impact

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ABSTRACT

The biomechanics of hip fractures has been studied by many authors in the past; however, predictions of the fracture location and character remain difficult and speculative[1,2]. The aims of the present study are threefold. First, to investigate whether proximal femur trochanteric and cervical geometrical metrics correlate with outcomes of dynamic drop tower testing carried out on human donor femurs. Second, to systematically investigate whether the combined evidence from organ level Finite Element Analysis (FEA), Xtreme CT data and high speed (HS) video data supports the hypothesis that failure of the proximal femur initiates in the cancellous bone and not the cortical bone under impact loading. Third, to use multi-scale FEA to investigate whether holes perforating the cortex of the proximal femur are associated with primary failure events as recorded per HS video data captured during impact.

We found measured peak force to correlate with minimum intertrochanteric cortical thickness (R^2=0.69) for the 15 specimens subjected to the drop tower test. Failure was predicted to initiate in the cancellous compartment for 14 specimens according to combined evidence from organ level FEA, Xtreme CT data and HS video data. We found evidence to suggest that holes perforating the cortex may be associated with primary failure events according to our multi-scale FEA.

We conclude that our systematic multi-scale and multi-modality analysis of failure initiation in the proximal femur under impact may provide new insight into a key question in osteoporosis related research which is: *what predisposes a hip to fracture*?

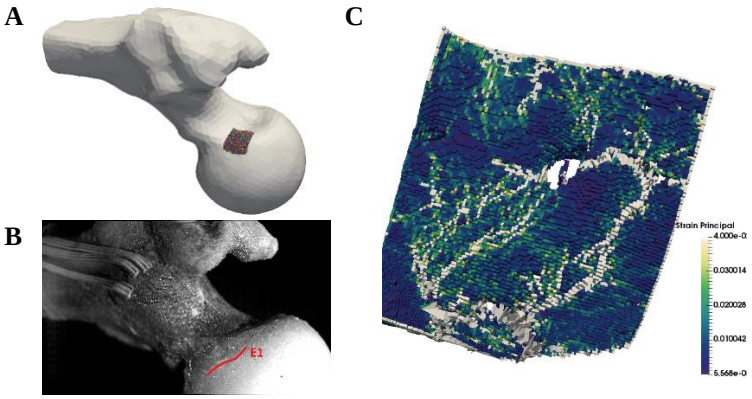

Fig. 1. *(A) Organ level FE model of a human proximal femur for a sample donor specimen with volume of interest (VOI) around fracture initiation site indicated. (B) Initial fracture indicated on HS video image. (C) Tensile principal strain distribution at the time of fracture according to micro level FEA shows high strains around a hole in the cortex.*

REFERENCES

[1] B. Helgason et al, "Development of a Balanced Experimental-Computational Approach to Understanding the Mechanics of Proximal Femur Fractures" *Med Eng & Phys*, 36(6):793-799, 2014.

[2] S. Nawathe et al, "Microstructural Failure Mechanisms in the Human Proximal Femur for Sideways Fall Loading" *J Bone Min Res*, 29(2):507-515, 2014.