BALANCED EXPERIMENTAL-COMPUTATIONAL APPROACH FOR UNDERSTANDING FEMUR FRACTURE MECHANICS

B. Helgason[1], S. Gilchrist[3], O. Ariza1[1,2], J.D. Chak[2], G. Zheng[3], R.P. Widmer[1], S.J. Ferguson[1], P. Guy[3], P.A. Cripton[3]

[1]IFB, ETH-Zürich, Switzerland; [2]University of British Columbia, Vancouver, Canada; [3]ISTB, University of Bern, Switzerland

Introduction

Elevated hip fracture risk is generally addressed either pharmacologically or through lifestyle interventions which can be expensive and difficult to administer. For these reasons, clinicians must carefully screen patients before implementing these solutions. In an attempt to increase the sensitivity of screening techniques we must understand what predisposes a hip to fracture. Our research introduces a protocol for studying this problem using a multiple modality approach.

Methods

The protocol is comprised of the following components; a) ex-vivo, biofidelic drop tower testing of donor specimens at fall speeds; b) high-speed imaging analyzed with digital image correlation (DIC) to determine surface strains, which will be used to validate FE models; c) detailed accounting of the energy present during the drop tower test based on load cell and high speed imaging data; d) organ level FEA of the drop tower test; e) micro level FEA of critical volumes of interest.

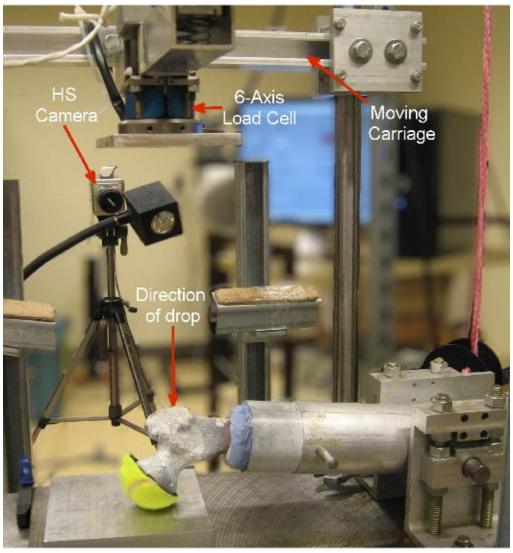

Figure 2: Drop-tower experimental setup.

For the present study we chose to present results from a specimen from our preliminary testing that failed in compression in the superior part of the femoral neck, a fracture case that is ideal for highlighting some of the limitations of the state of the art knowledge in hip fracture mechanics and, by contrast, the strengths associated with our approach.

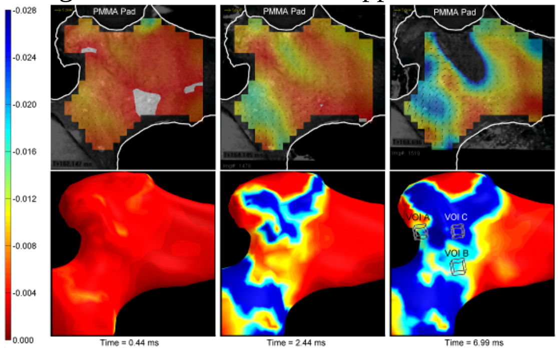

Figure 2: Min principal strain distribution according to DIC (above) and FEA (below).

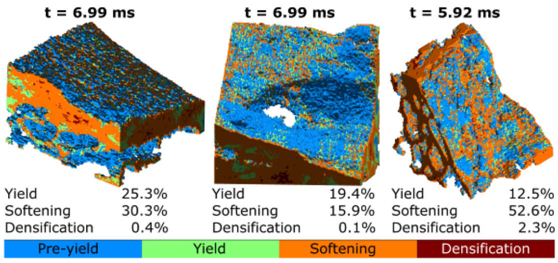

Figure 3: Micro-level FE results of critical VOIs.

Results

Fracture in the femoral specimen initiated in the superior part of the neck. Measured fracture load was 3’760 N, compared to 4’659 N predicted based on the FEA. DIC showed compressive surface strains as high as 7.8% prior to fracture. Voxel level results were consistent with high-speed video data and helped identify hidden local structural weaknesses.

Discussion

We produced a clinically relevant fracture by using a drop tower test with impact parameters representative of a fall to the side from standing height. Additionally, we found that the nested explicit finite element method allowed us to identify local structural weaknesses, such as cortex perforating holes, associated with femur fracture initiation and progression.