Development and Validation of a Human Pelvis Finite Element Model for Lateral Impacts

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The objective of this study was to develop and validate an injury predictive finite element model of the pelvis during lateral impact. Automotive accidents involving side impacts, particularly those with door panel intrusion, contribute significant injuries to the pelvis. Salzar et al. (2009) tested 12 cadaver pelvis specimen, all males with an average age of 60 years old, of which were denuded of soft tissues except for those connecting the sacrum and two ilium. These tests analyzed the load distribution through the anterior and posterior portions of the pelvis during instances of both acetabulum and iliac wing loading. The nature of Salzar's tests make them suitable for evaluating the isolated mechanical response of the sacroiliac joints and pubic symphysis of the pelvis in finite element simulations.

CAVEMAN (Computational Anthropomorphic Virtual Experiment Man) is a high-fidelity human body FE model based on a 50th percentile human male, developed to predict response and injury in high rate loading conditions. The material properties for the CAVEMAN pelvis were obtained from literature for the cortical bone, inter-pubic disk, pubic ligaments, as well as the joint cartilage. A parametric study was performed in order to optimize the material properties of the trabecular bone. Recently, Hammer and Stefan (2019) have highlighted the lack of characterization of the mechanical properties of human sacroiliac connective tissues, thus an effort was made to quantify sacroiliac joint response. The three dimensional geometry of the sacroiliac joint was validated based on anatomical reconstructions reported in Steinke et al. (2010). Next transverse isotropic hyper-elastic material constants for the sacroiliac ligaments were determined by fitting the model response to low strain, quasi-static data (Miller 1987) and high strain, high rate impact data (Salzar et al. 2009). This work contributes a novel three-dimensional representation of the human sacroiliac joint with nonlinear material properties validated in multiple loading conditions. The response of the CAVEMAN model compared favorably to both test cases and the injuries reported in simulations matched those occurring in the cadaveric tests. Furthermore, an injury risk threshold study was performed to quantify fracture risk of the model.

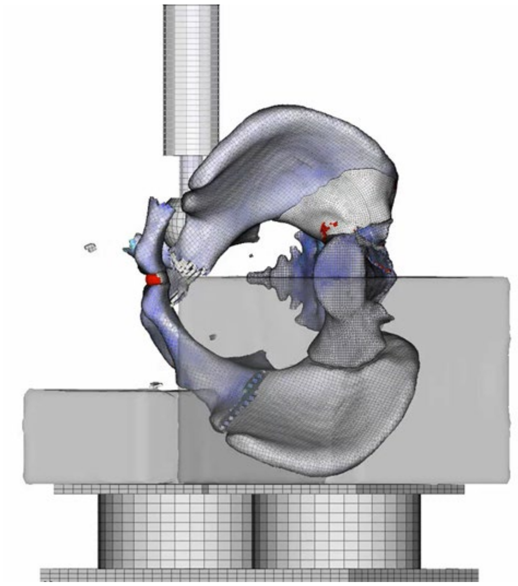

Figure 1: Acetabulum impact of the CAVEMAN pelvis model, testing conditions matching Salzar 2011.

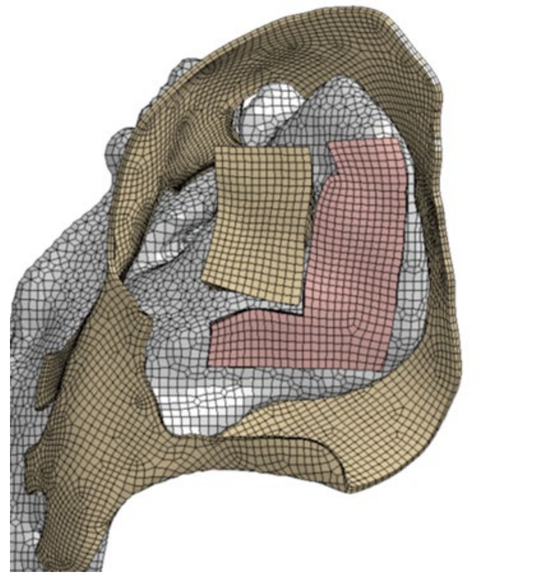

Figure 2: Three dimensional finite element representation of the sacroiliac joint (lateral-sacrum view).

References:

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