Evaluation of Correlations between Equivalent CT Density and Material Properties of Lower Limb Bones

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ABSTRACT

The majority of occupant lower extremity (LEX) injuries in automotive crashes occur in the knee-thigh-hip (KTH) complex. While many Finite Element (FE) models have been developed to assess KTH injury mechanisms, their bone models were usually defined as isotropic. Models which account for heterogeneous nature of bone are crucial for better predicting mechanical and injury responses. Recently, some correlations between Computed Tomography (CT) scan data and the cortical bone material properties were established. To figure out the best correlation for the LEX bones, this study evaluated the consistence of the reported correlations and then optimized the parameters of the comparably best relationship. Sixteen coupon samples harvested from the tibial and femoral shafts of four post mortem human subjects were fine meshed based on geometries reconstructed from μ-CT data. The FE coupon models were then assigned with material properties according to elastic moduli, ultimate stresses based on CT Hounsfield Units, equivalent mineral densities, and different literature correlations. Finally, Quasi-static (strain rate of 0.05 %/s) and dynamic (strain rate of 100 %/s) tensile tests of corresponding coupon models were simulated, with the same boundary conditions of the experiments. The force-displacement time history, surface strain field contour, and fracture location of each coupon model were compared with test observations. The global deviations of the coupon model responses in comparison to physical experimental responses under various conditions were analyzed and compared. The parameters of the best correlation were then optimized to minimize its coupon model global response deviation with the test ones. We hypothesize that the results of this study will help establish a more accurate correlation for predicting the material properties of lower limb bone directly from μ-CT data and ultimately facilitating a better LEX injury prediction.