

A New Corridor Development Method for Clavicle Finite Element Model Validation

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ABSTRACT

The objective is to develop structural (force-deflection) and material level (force-strain) response corridors for clavicle finite element (FE) model validation. Corridors were frequently used for validating FE models to ensure its accuracy to predict biomechanical response. However, most of the corridors that exist in the literature were reported in terms of structural behavior, e.g., force-deflection. Such a structural description has been shown to be often insufficient for the development of models which accurately predict fracture. Untaroiu et al. (2006) showed that, for example, it is possible to tune a finite-element model of the femur to match an experimental forcedeflection response well with a variety of material models; however, the choice of material model can substantially affect the strain response. Such inaccuracy in the strain response will limit the ability of the model to predict fracture, as strain is often used as the metric for injury timing. Thus it is desirable to validate an FE model using both the structural (force-deflection) and material (e.g. strain) response. Clavicle was selected in this study because no clavicle response corridors exist in the literature. To develop clavicle response corridors, clavicles were loaded to failure under either axial-compression or three-point bending to mimic the loading conditions in side impact and frontal impact. Ten clavicles were tested in each configuration. Force and deflection response was documented for each test. In addition, four uni-axial strain gages were adhered around the perimeter of each clavicle crosssection at the location of maximum posterior concavity where failures most often occur, to record clavicle strain response during loading. The neutral axis and peak strain around the cross-section with strain gauge attached was calculated based on Bernoulli beam theory. The neutral axis angle between the component test and in-laboratory sled test was compared to ensure the validity of the boundary condition in components tests. The neutral axis angle is close between component tests and sled test (no statistical significance): 73 ± 8 degree for axial-loading vs 75 degree for side impact test; 78 ± 4 degrees for three-point-bending vs 80 degree for frontal impact test. Then the peak strain calculated above was used to construct the material level corridor: force vs peak strain corridor. The force-deflection responses recorded in the experiments were also used to develop structural level corridor: force-deflection corridor. In addition, all the corridors obtained above were developed by an ellipse-based corridor development method that is based on a previous corridor development method by Lessley(2004). Both structural and material level clavicle corridors for each loading condition were obtained in this study. Material-level corridors can provide higher confidence when validating a FE model, and therefore give a higher ability to predict injury. The method used in this study could be expanded to construct corridors for other components of the human body for FE model validation.