

A parametric study of hard tissue injury prediction using finite elements: consideration of geometric complexity, subfailure material properties, CT-thresholding and element characteristics

C. Arregui-Dalmases; E. Pozo de Dios; S. Duprey; F.J. López Valdés; A. Lau; D. Subit; R. W. Kent

Abstract-

Objective:

The objectives of this study were to examine the axial response of the clavicle under quasistatic compressions replicating the body boundary conditions and to quantify the sensitivity of finite element–predicted fracture in the clavicle to several parameters.

Methods:

Clavicles were harvested from 14 donors (age range 14–56 years). Quasistatic axial compression tests were performed using a custom rig designed to replicate in situ boundary conditions. Prior to testing, high-resolution computed tomography (CT) scans were taken of each clavicle. From those images, finite element models were constructed. Factors varied parametrically included the density used to threshold cortical bone in the CT scans, the presence of trabecular bone, the mesh density, Young's modulus, the maximum stress, and the element type (shell vs. solid, triangular vs. quadrilateral surface elements).

Results:

The experiments revealed significant variability in the peak force (2.41 ± 0.72 kN) and displacement to peak force (4.9 ± 1.1 mm), with age ($p < .05$) and with some geometrical traits of the specimens. In the finite element models, the failure force and location were moderately dependent upon the Young's modulus. The fracture force was highly sensitive to the yield stress ($80\text{--}110$ MPa).

Conclusions:

Neither fracture location nor force was strongly dependent on mesh density as long as the element size was less than 5×5 mm². Both the fracture location and force were strongly dependent upon the threshold density used to define the thickness of the cortical shell.

Index Terms- Finite element modeling, Fracture prediction, Clavicle, Side impact, Sensitivity study

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