Modelling the Impact Response of Cranial Bone

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ABSTRACT

Linear and depressed skull fractures are frequently mechanisms of head injury and are often associated with traumatic brain injury. Accurate knowledge of the fracture of cranial bone can provide insight into occurrences of lesions of soft neural tissue and can help in designing energy absorbing head protection systems and safety helmets. Cranial bone is a complex material comprising of a three-layered structure: external layers consisting of compact, high-density cortical bone and a central layer consisting of a low-density, irregularly porous structure.

Cranial bone specimens (n=63) were extracted from the parietal and frontal cranial bones of 8 cadaver subjects (F=4, M=4; 81±11yrs.). Prior to testing, specimens were scanned using a µCT scanner (resolution=56.9µm). The specimens were tested in three-point bend set-up at dynamic speeds (0.5, 1 and 2.5 m/s). Each test was captured using high-speed video (~20,000fps) and the corresponding force-deflection curves recorded. The mechanical properties calculated for each specimen included: sectional elastic modulus, maximum force at failure, energy absorbed until failure, average strain rate and maximum bending stress. Structurally detailed 3D finite element (FE) models were developed from the µCT data and validated against the experimental results using Abaqus 6.7.

The mechanical properties were consistent with those previously reported in the literature. The viscoelastic properties of cranial bone were evident from the results. The cranial bone was significantly stiffer at the higher strain rates. The cranial sampling site was also a factor in the resulting mechanical properties. The frontal bone tends to be thicker, less porous and have a higher % bone volume than the parietal bones. It was possible to produce high quality FE meshes of the specimens from µCT data. The results from this work can be used to improve the skull material and failure definitions in the UCD 3DFE model of the skull-brain complex, currently used to aid helmet design.

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