

On the use of a patient-specific rapid-prototyped model to simulate the response of the human head to impact and comparison with analytical and finite element models

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Accepted 24 March 2004. Available online 21 May 2004.

Abstract

Every year, thousands of fatalities result from head injuries, the majority of which are sustained in automotive accidents. In this paper, an experimental study of the response of the human head to impact is presented. A rapid prototyped model of a human head was generated based on high-resolution magnetic resonance imaging (MRI) scan data. The physical model was subjected to low velocity impacts using a metallic pendulum and a sensitivity study was performed to explore the influence of various parameters, including mass and velocity of the impactor, on the response. The experimental response characteristics are compared with predictions from an analytical model as well as with numerical predictions from finite element (FE) models generated from the same MRI data set. The results from the experimental tests closely match those predicted by both the analytical and the FE models and thus provide us with substantive corroboration of all three approaches. The remarkable agreement obtained between the measured response characteristics of rapid-prototyped skulls and numerical (FE) models obtained from in vivo MRI data clearly demonstrates the potential use of rapid-prototyping to generate experimental models for head impact studies, and, more generally, for the study of the response of complex bio-structures to loading. In addition, the quantitative and qualitative accuracy of the predictions from the analytical model is clearly demonstrated by the FE and experimental corroboration. In particular, the analytical prediction that, as impact mass drops the impact duration becomes increasingly short, appears to be substantiated, which has important implications for the onset of high pressure and shear strain gradients in the brain with potentially deleterious effects.

Author Keywords: Impact biomechanics; Head injury; Rapid prototyping; Finite element modelling; Analytical modelling
