

A Kinematically Biofidelic Surrogate Cervical Spine for Axial Compressive Impacts

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ABSTRACT

Axial compressive injuries to the cervical spine can be devastating. Despite a great body of research on the subject, spine kinematics during axial impacts are not fully understood. The anthropometric test device most widely used for impact testing is the Hybrid III which was designed to provide a biofidelic response in high speed frontal and rear-end impacts[1]. It is not biofidelic in axial compressive impacts [2, 3]. Accordingly, we set out to design and build a repeatable surrogate spine that is kinematically biofidelic in the sagittal plane for conducting inverted axial compressive impacts.

Design Features:

T1 through C0 were machined of aluminum (figure 1.) and intervertebral discs were constructed of serrated rubber sheets. The flexion-extension centers of rotation and ranges of Motion for C7/T1 to C0/C1 are based on published in vivo data [4]. The centers of rotation combine with vertebral dimensions to mimic ex vivo ratios of extension stiffness to flexion stiffness [5]. An adjustable spring-anchored follower load is applied to simulate in vivo musculature.

Initial Testing Methodology:

A series of evaluation impacts has been performed. 9 drops in aligned posture from a 0.5 m drop height incorporating 3 levels of pre-load have been conducted on a custom built drop tower utilizing an existing surrogate head model. These tests were filmed at 1000 fps (Phantom V9 Vision Research) and the impact platform force sampled at 146 kHz.

Results:

Qualitatively, the cine playbacks demonstrate strong kinematic repeatability. The vertebrae compress until they “bottom out” at which point the head moves into flexion. Increasing pre-load from 0 to 104 N caused the vertebrae to “bottom out” sooner but did not change the observed motion. Peak head impact forces varied from 8.4 to 10.5 kN (figure 2.) and the differences were not statistically significant ($P > 0.05$) among the 3 pre-load groups.

Conclusion:

Initial experience suggests that the surrogate spine's response is repeatable with improved kinematic biofidelity. Further validation studies have been planned to compare the axial and sagittal bending stiffnesses under quasi-static loading to published ex vivo data.

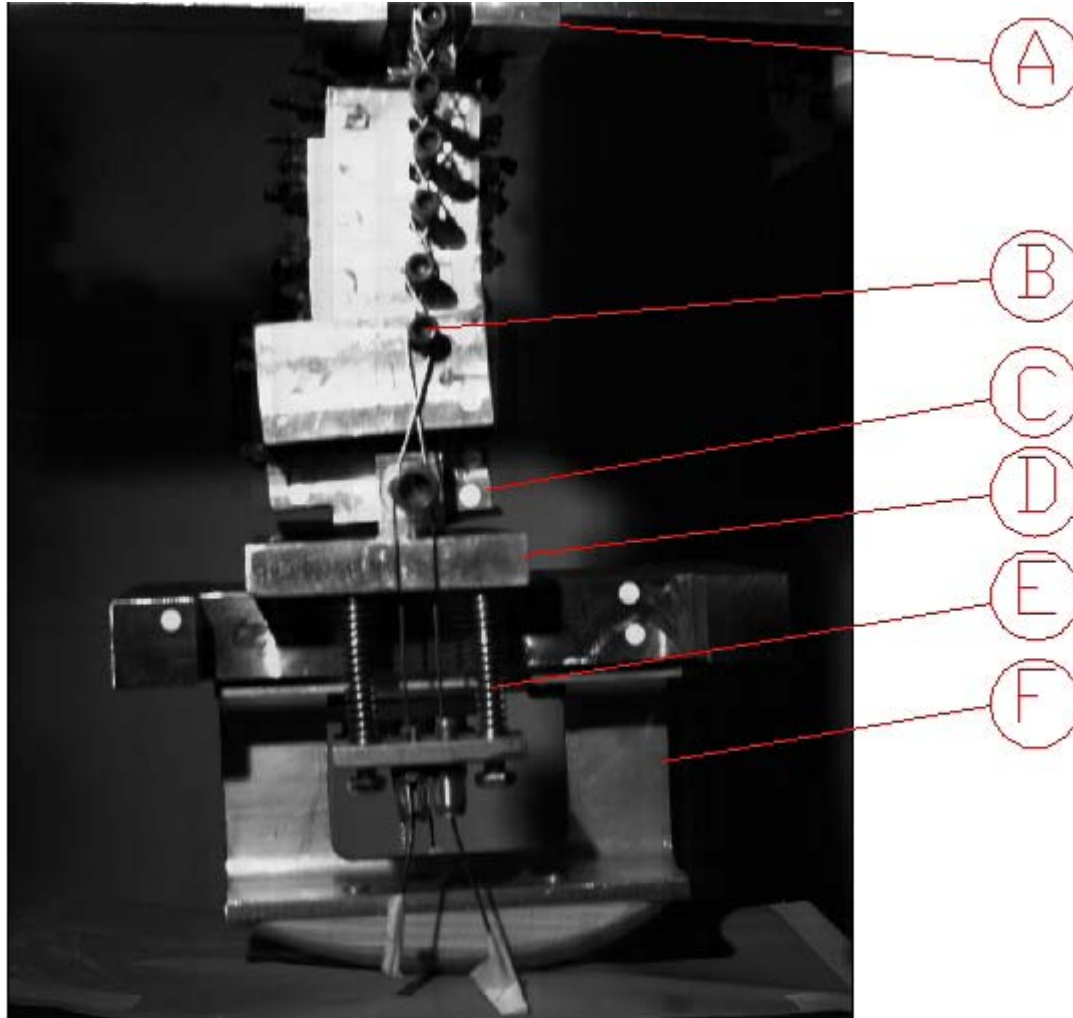


Figure 1: Image of surrogate spine/head just before impact.
A. T1 attached to carriage of drop tower. B. Bolts locate

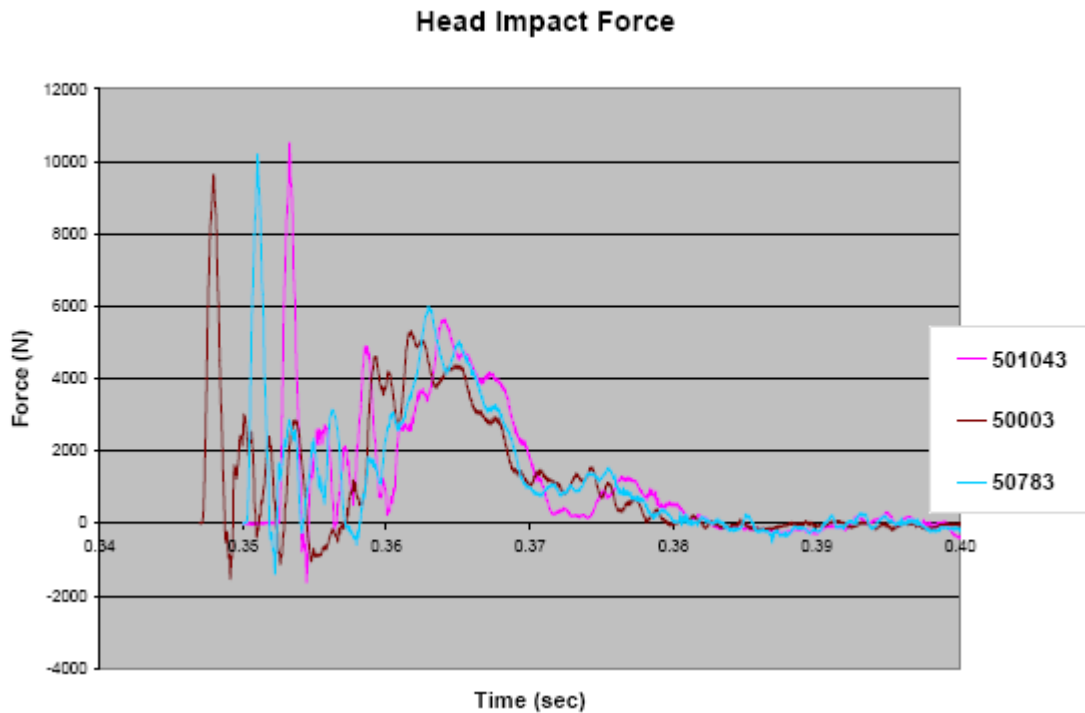


Figure 2: Typical head impact force traces for the three preloads used. (Pink = 104 N, Cyan = 78 N, Brown = 0 N)

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