H93 Biomechanical Evaluation of Frangible Skull Surrogates to Blunt Ballistic Temporo-Parietal Head Impact

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After attending this presentation, attendees will obtain additional knowledge on the biomechanical testing of trauma-indicating skull surrogates for use in forensic investigation.

This presentation will impact the forensic science community and aid attendees by providing additional morphological fracture data from laboratory-based testing of Postmortem Human Subjects (PMHS) exposed to blunt impacts in additional to a biomechanical comparison between the PMHS and frangible skull surrogates.

Various breakable or frangible "trauma indicating" head models have been proposed over the years by the automotive safety community.[1,2] Effort was shifted to the improvement and development of nondestructible technologies with frangible models never making it to a production level. The need for a frangible head model has since resurfaced for forensic applications. Forensic applications of injury biomechanics is a unique and emerging field.

The "skin-skull-brain" model was developed by Thali et al. to reproduce fracture patterns seen in forensic cases due to blunt and ballistic traumata.[3,4] Known cases of blunt and ballistic traumata were used as validation of the model's fracture characteristics. While good agreement was found between fracture patterns, no biomechanical considerations such as biomechanical response (force and deformation characteristics) or fracture tolerance were addressed in the study.

The goal of the current research was to evaluate the biomechanical response and fracture tolerance of a frangible skull model to blunt and ballistic traumatic conditions. Biomechanical response, fracture tolerance, and resulting fracture patterns were compared to those produced in PMHS exposed to the same traumatic conditions. Two types of frangible surrogates were evaluated. Three material types (10% gelatin solution, lead shot surrounded by Styrofoam, and water) were used to represent intracranial contents to evaluate the effect of interior boundary condition. A leather chamois was used as a skin covering over the impact site. A 103 gram, 1.5 inch-diameter impactor was launched at 20 m/s from a custom air cannon at the surrogate/PMHS which was suspended via a lightweight cable. An accelerometer was embedded in the impactor to measure impact force via Newton's Second Law. High speed digital video was captured at 10,000 frames per second with two Kodak HG100k cameras mounted orthogonally to the specimen. PMHS specimens were tested with soft tissue intact for the first impact. Following the first impact, a second impact was performed following defleshing of the specimen to obtain forced-deformation response under both conditions for comparison. Force-deformation plots were generated from the PMHS tests for comparison to the frangible surrogate responses. Fractures in PMHS were photographed for morphological comparison to the surrogate tests.

The sphere designs investigated in the current study demonstrated an increased tolerance to fracture compared to PMHS. The fracture pattern created in the one fractured sphere did not compare well with the PMHS fracture patterns, but may be an artifact of the seam created by joining the two-piece skull model. The effect of internal boundary condition was evaluated by assessing three different brain substitutes. The 10% gelatin solution provided the maximum resistance to local deformation while the lead shot surrounded by Styrofoam provided the least resistance. The water-filled sphere resulted in the most biofidelic force-deformation characteristics indicating it may be the more ideal internal boundary condition. Additional testing is necessary before statistical conclusions can be reached.

These results indicate material properties (polyester versus polyurethane) and structural composition are important factors that should be evaluated for the current frangible skull surrogate design. In addition to modifications to the structure of the model, consideration is needed for a biofidelic soft tissue covering.

References:

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Bone Trauma, Skin-Skull-Brain, Biomechanics