A91 The Effects of Input Energy and Impact Surface on Cranial Fracture Patterns

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Learning Overview: After attending this presentation, attendees will have learned about cranial fracture patterns generated in human cadaver head impact experiments performed at two levels of input energy with three impact surfaces of different shapes.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by contributing documentation of experimentally generated human cranial fracture patterns. These data provide a baseline for understanding the influence of input energy and impact surface shape on cranial fracture production and evaluating fractures in forensic cases.

Several extrinsic variables are expected to influence cranial fracture patterns, including the magnitude and duration of force, impactor mass and velocity, and the contact surface between an implement and skull. While these relationships may be theorized using thought experiments, experimental data can help link these mechanical inputs with fracture outputs.[1]

This study examines the effects of two extrinsic variables: input kinetic energy and impact surface, on cranial fractures. Previously, experiments were performed on 12 Postmortem Human Subject (PMHS) heads using three implements with different contact surfaces.[2] The current study builds on this work to assess fracture patterns obtained at a comparatively higher input energy. This study aimed to: (1) document mechanical response and fracture data for these higher-energy experiments, and (2) compare results obtained in the current study to those from previous experiments to investigate the effects of input energy and impact surface on fracture behavior.

Mid-parietal impact experiments were performed on 12 unembalmed, upright PMHS heads. The impact methodology has been described in detail in a previous publication.[2] Input energy was increased relative to the original experiments primarily via the addition of impactor mass. The same three implements with different contact surfaces were used in the current study: a small, focal surface (1.1-inch diameter cylinder base); a broad, curved surface (length of a 2.5-inch diameter, 2.5-inch long cylinder); and a broad, flat surface (3-inch diameter cylinder base). Characteristics of the resulting fractures were assessed for each experiment. Maximum Defect Diameter (MDD) of non-linear defects was measured with sliding calipers.

The average input energy (E_i) of the current experiments was 180.07±23.02 J, which represented a 67% increase in E_i from the previous experiments (106.11±8.80 J). While the average energy absorbed by the head (E_a) was significantly higher in current (86.31±25.31 J) versus previous (55.21±10.35 J) experiments (p=.0007), there was no statistically significant difference in average peak force obtained in higher-energy (6980.8±2036.9 N) versus lower-energy (6415.82±2155.92 N) experiments (p=.52).

The results indicated greater complexity and severity of fracture in higher-energy versus lower-energy impacts. Crania in the higher-energy group exhibited depressed and comminuted fractures more frequently than those in the lower-energy group. Only the higher-energy impacts produced fractures crossing the midline. However, overlaps in the results obtained between energy groups, particularly with broader impact surfaces, suggested that the degree of damage might be substantially influenced by individual properties of the cranium.

The results also suggested differences in the appearance and size of defects based on contact surface. The focal and curved surfaces more frequently produced localized depressed and circumferential fractures, whereas the broad, flat surface more frequently produced patterns involving only linear fractures. The flat surface (MDD=63.15±7.21mm) produced larger defects than the focal surface (MDD=35.02±10.25mm), while the curved surface produced defects intermediate in size (MDD=47.21±19.45mm). However, all three implements produced defects larger and/or smaller than the impact surface diameter. Variation in contact area is one factor that could explain this result. The three surfaces tested have different expected contact areas, but individual factors such as cranial curvature may affect the actual area of contact between these surfaces and a head.

The size and appearance of defects obtained in this study supported the general conclusions that focal, penetrating depressed fractures can likely be associated with similarly focal surfaces, whereas larger circumferential and depressed fractures likely indicate broader surfaces. However, the relationship between impact surface and defect size is highly variable and therefore cannot be precisely reconstructed, especially in the case of broad defects.

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Reference(s):

1. Berryman, H.E., J.F. Berryman, and T.B. Saul. 2018. Bone Trauma Analysis in a Forensic Setting: Theoretical Basis and a Practical Approach for Evaluation. In *Forensic Anthropology: Theoretical Framework and Scientific Basis*, edited by C.C. Boyd and D.C. Boyd, 213–34. Chichester, West Sussex, UK: John Wiley & Sons Ltd.
2. Isa, M.I., T.W. Fenton, A.C. Goots, E.O. Watson, P.E. Vaughan, and F. Wei. 2019. Experimental Investigation of Cranial Fracture Initiation in Blunt Human Head Impacts. *Forensic Science International* 300: 51–62.

Trauma Analysis, Cranial Fracture, Blunt Force Trauma