A78 Understanding the Role of Contact Area in Adult Cranial Fracture Variation

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After attending this presentation, attendees will better understand the relationship between skull-implement contact area, location of fracture initiation, and fracture characteristics in controlled blunt impact experiments performed on adult human heads.

This presentation will impact the forensic science community by helping to clarify the role of implement shape in blunt force impacts, which will inform investigators' interpretation of adult cranial trauma.

The purpose of this presentation is to present new data on shaped impact experiments with adult human heads and to examine contact area between the cranium and an impacting surface and its effect on fracture initiation and fracture characteristics.

Seven unembalmed adult male heads were hit in a series of controlled blunt impact experiments, according to a protocol discussed previously.[1] Impacts were delivered to the center of the right parietal using various shaped implements. These included two flat (3" diameter and 1" square) and two curved (2" diameter hemispherical and 1" diameter spherical) aluminum impactors. High-speed photography captured fracture initiation and propagation in these experiments.

Contact area data was recorded for each impact experiment. Pressurestat contact paper was laid onto the center of the parietal and an impact was delivered at a pre-failure level. The resulting contact area impression was measured using digital calipers. This procedure was repeated ten times per specimen-implement pair to obtain average contact area. Additionally, one specimen was Computed Tomography (CT) scanned and computational Finite Element Analysis (FEA) was performed using Abaqus/CAE standard software to model the effect of contact area on maximum principal stresses.

The results showed that implement shape influences contact area. Significant differences in average contact area were recorded between the 1" spherical (2.88±1.02mm^2), 2" hemispherical (9.72±2.42mm^2), and 3" flat (39.38±13.89mm^2) implements. In impacts with two different specimens, the 1" flat implement produced significantly different contact areas (12.78±8.51mm^2 vs. 58.29±9.90mm^2). This indicated the importance of cranial curvature; an impact with the same implement results in a smaller contact area on a more curved cranial surface than a less curved surface.

Contact pressure generated under the Point Of Impact (POI) varied directly with contact area and corresponded with location of fracture initiation and fracture type produced. The 1" spherical implement generated the smallest contact area and highest pressure (2068±633MPa). This was the only impact to produce depressed fracture. Contact pressure in the 2" hemispherical impact was significantly lower (796.6±221MPa). High-speed photography showed that this impact resulted in a POI-initiated linear fracture, followed by a curvilinear fracture near the POI. Pressure in the 3" flat impact was significantly lower than .in either curved impact (232.3±66.4MPa). In this impact, a linear fracture initiated peripherally rather than at the POI.

When contact area was large, an impact with the 1" flat implement generated pressure statistically similar to the 3" flat impact (207.9±34.4MPa) and produced a similar pattern of fracture (peripheral-linear). When contact area was small, an impact with the 1" flat implement generated pressure statistically similar to the 2" hemispherical impact (558.3±308.9MPa). In this case, fracture also initiated at the POI.

Computational modeling helped explain the fracture data. FEA models showed that a large contact surface produced low stresses at the POI, but high tensile stresses at the cranial sutures; this resulted in the initiation of linear fracture peripheral to the POI. At the same energy, a small contact area produced higher stresses and failure at the POI, potentially with depression.

The results of this study suggest contact area, more precisely than implement shape, may explain variation in fracture patterns observed in adult cranial impacts. At similar energy levels, contact area determined the pressure generated under the POI. Contact pressure, in turn, influenced fracture initiation (POI vs. peripheral) and fracture type (depressed vs. linear). Contact area decreased with decreased implement size, but also with increased cranial curvature. These experimental results may help explain differences in cranial fracture patterns observed between individuals or in impacts to different areas of the skull.

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Reference(s):

1. Fenton T.W., Isa M.I., Vaughan P., and Haut R.C. Experimental and computational validations of the initiation and propagation of cranial fractures in the adult skull. Proceedings of the American Academy of Forensic Sciences, 67th Annual Scientific Meeting, Orlando, FL. 2015.

Blunt Force Trauma, Cranial Fracture, Trauma Biomechanics