H50 Biomechanics of Blunt Ballistic Impacts to the Forehead and Zygoma

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Upon reviewing this poster, investigators will gain insight into previ- ously unknown biomechanics governing the impact response and tolerance of the forehead and face to blunt ballistic impacts. Injury criteria will be explored to identify key engineering parameters linking specific fracture morphology to impact characteristics.

This presentation will affect the forensic community by offering a totally unique scientific data set on skull and facial fracture tolerance and morphology due to blunt ballistic impacts. Investigators will gain insight into the biomechanics of skull and facial fracture and be presented with a complete set of fracture morphology data with linked with biomechanical parameters measured through leading edge instrumentation. This data will assist investigators in forensic reconstruction of skull and facial trauma.

Circumstances leading to skull and/or facial trauma may not always be known due to the lack of witnesses, inability of the patient to recall or artic- ulate the events that led to the trauma or patient death. A forensic biomech- anist may be brought in to work with a forensic pathologist or a forensic anthropologist to relate the mechanics involved with causing particular types of fractures. He/she may perform evaluations of various impact scenarios using biomechanical surrogates and injury criteria to assess the likelihood of producing fractures that match the physical evidence. Unfortunately, the current biomechanical surrogates and injury criteria developed by automotive safety researchers fall short of providing necessary information for the recon- struction of specific fracture types due to a lack of controlled impact studies. Head injury criteria and biomechanical data are needed to extend the under- standing behind blunt ballistic impact tolerance and for fracture-specific risk assessment. The primary goal of this research was the advancement of fracture-specific head injury criterion for the assessment of localized blunt ballistic impacts to the forehead and zygoma.

Experimental impact testing was performed on five (5) isolated, unem- balmed postmortem human subjects. Specimens were impacted to the frontal and zygoma regions of the face with a 38 mm diameter rigid impactor, launched via a ballistic air cannon. Specimens were instrumented with a nine-accelerometer array to document global head response. Local bone response was measured by Rosette-style strain gages attached to the outer cortical layer surrounding the impact sites. Soft tissue was left intact at the impact sites. Impact force was calculated from a 20,000 g accelerometer mounted to the rear aspect of the impactor. High speed video captured the impact at 10,000 frames per second. Post-test CTs were obtained along with detailed autopsies documenting resulting fracture patterns. Fracture criteria were explored through logistic regression analysis of measured parameters and compared with previously developed head injury criteria. Goodness of fit was evaluated by the chi-squared statistic, p-value and Nagelkerke R^2. Significance levels were set at $p < 0.05$.

Twenty (20) impacts were performed in total with ten impacts to the frontal bone and ten to the zygoma regions. Of the ten impacts to the forehead, fractures were produced in four cases. Fractures ranged from local linear to depressed, comminuted. Of the ten impacts to the zygoma, fractures resulted in four cases. Fractures were primarily of the "tripod" type in addition to comminuted fracture of surrounding bone. Peak fracture forces for the frontal bone and zygoma ranged between 4,413 to 9,438 N and 575 to 2,746 N respectively. Acceleration data from the array indicates that the skull does not respond as a rigid object under these loading conditions which limits the ability to utilize the nine-accelerometer array for estimating center- of-gravity acceleration. This indicates deformation-based measures should be investigated further in future experimental studies.

Logistic regression results indicate that strain-based measures were statistically significant predictors of fracture followed by acceleration of the head ($P < 0.05$). While impact force demonstrated increase risk of fracture with increasing force, this was not a statistically significant predictor of fracture.

Current biomechanical models are not equipped to measure skull defor- mation or strain. These measures are currently most effectively measured through finite element models. The basic biomechanical data from this study will first and foremost serve as validation for advancement of finite element models of the head to the blunt ballistic impact environment. Additional efforts can then be put forward into development of an advanced fracture-prediction model. The current results indicate that effort should begin with strain-based criterion for blunt ballistic forehead and facial fracture.

Biomechanics, Skull Fracture, Ballistics

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