PMHS Chin Injury Threshold Testing

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Background
In child restraint system (CRS) testing, it is common for the Hybrid III child anthropomorphic test device (ATD) to experience an elevated head impact criterion (HIC) value even though the head of the dummy may not have contacted any foreign structures. These high HIC values in many cases are derived from the chin of the ATD contacting its anterior chest. Previous research conducted at the Injury Biomechanics Research Laboratory (IBRL) at The Ohio State University revealed that the chin of the Hybrid III 10 year old child ATD was moderately biaxial when impacted at energy levels typically recorded in FMVSS 213 sled testing. The energy levels used in this previous testing were found to be below the injury threshold of the human mandible.

It has been documented that vehicle crashes are the single leading cause of facial injury, which include LeFort I & II fractures [1]. Published research to date focusing on injuries to the mandible and face due to blunt chin impact vary in their findings. Hopper et al. found that an impact force of 5,250 N was required for mandibular fracture [2]. When Huelke cites subcondylar fractures occurring at forces between 2,000-2,500 N [3]. Therefore, a new test series was developed to impact the mandible of four post-mortem human subjects (PMHS) at increasingly higher energies to document the injury threshold of the mandible and report the associated injuries.

Objectives
- Report the types of injury associated with blunt mandibular impact
- Document the injury threshold of the mandibular region
- Record force at time of injury
- Record chin deflection at time of injury
- Calculate the initial stiffness of the human chin in response to a 1.6 m/s impact to the mandible

Methods
Four PMHS mandibles were impacted at increasing velocities using a 26.8 kg rigid impactor. Low-speed tests were conducted at 0.8 m/sec before and after each impact of increasing energy in order to exercise the tempromandibular joint and provide a baseline response of the chin for injury identification. Each subsequent high-energy test increased in energy by 150% from the previous test. Computed tomography (CT) and autopsy were used to document injury. PMHS were available through the willed body donor program at The Ohio State University and all IRB protocols were followed. The anthropometry of each subject is shown Table 1.

Test Setup
A fixture to hold the PMHS heads for the chin impact tests was designed and fabricated as shown in Figure 1. The PMHS was fixed on each reaction surface using multiple screws through the skull to restrict motion to the mandible only. The orientation of the PMHS relative to the ram was consistently maintained such that all the impact energy generated by the ram was transmitted to the chin. The deformation of the chin was measured using a linear potentiometer on the ram and high speed photography (1000 frames/sec). Force, measured by a six-axis load cell on the front of the impactor, and the displacement data were then used in evaluating chin stiffness.

Results and Discussion
Changes in the baseline force response were used as an indication that injury occurred during testing. Figure 2. This figure shows the force-time history for all impacts to subject Chin04. Bold lines indicate the injury-causing impact and the subsequent baseline response. Table 2 shows the injury description, force at time of injury, chin deflection at time of injury, and initial chin stiffness for each subject. Injuries include LeFort I & II fractures equaling to AIS level 2 injuries. The average deflection at injury was 18.42 mm. The average force at injury was 5236 N, agreeing with the results of Hopper et al. [2].

Conclusions
- Multiple mandibular fractures and LeFort I & II fractures were documented
- Average force at time of injury was 5236 N
- Average displacement at time of injury was 18.42 mm
- Average initial stiffness of the chin was 470 N/mm

References