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 injury 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 biofidelic 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. (1994) found that an impact force of 5,250 N was required for mandibular fracture[2], while Huelke et al. (1983) cites subcondylar fractures occuring at forces between 2,000-2,500 N. 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 temporamandibular 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.

Table 1. PMHS characteristics

Test #	Age (year)	Height (mm)	Weight (kg)	Gender	Head Breadth (mm)	Head Length (mm)	Head Height (mm)
Chin01	66	1727	88.5	M	161	177	226
Chin02	50	1690	88.6	M	139	188	227
Chin03	47	1745	82.1	M	155	210	182
Chin04	80	1829	72.1	M	161	185	222
Avg ± St. Dev.	61 ± 15	1748± 59	83± 8	-	154± 10	190± 14	214± 22

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.

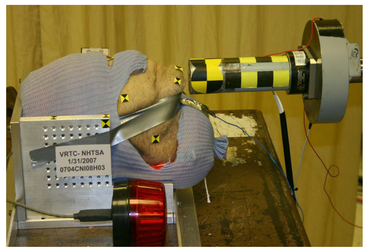

Figure 1. PMHS test setup

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 equating 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. (1994).

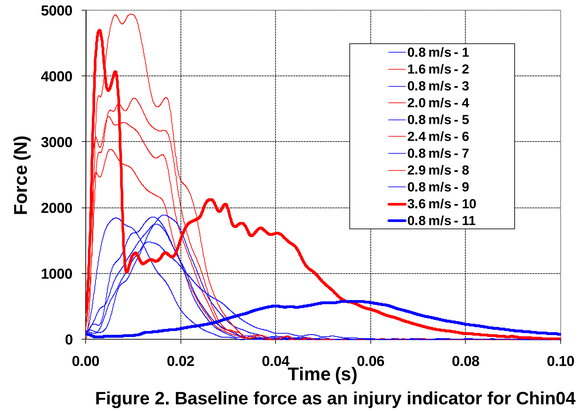

Figure 2. Baseline force as an injury indicator for Chin04

Table 2. Test result summary

Test #	Force at Injury (N)	Deflection at Injury (mm)	Stiffness for 1.6 m/s Impacts (N/mm)	Injury Description	AIS Code[4]
Chin01	4736	14.54	476	Multiple mandibular closed fractures lateral to the midline on the body without ramus involvement	250604.1
				Bilateral dislocation of the Temporomadibular joint	251604.2
Chin02	6722	26.11	605	No injury to mandible or TMJ	
				LeFort II fracture to maxilla with horizontal fracture of maxilla. Fracture approaches orbit on right side	250804.2
Chin03	4790	22.95	322	Multiple mandibular closed fractures lateral to the midline on the body without ramus involvement	250604.1
				LeFort I fracture to maxilla	250804.2
Chin04	4697	10.07	475	Multiple mandibular closed fractures lateral to the midline on the body without ramus involvement	250604.1
				LeFort II fracture of maxilla with the fracture extending through the body of the maxilla and down the midline of the hard palate	250806.2

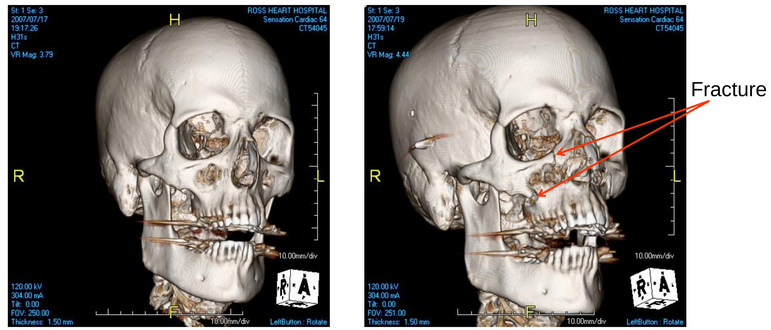

Figure 3. Pre-test (left) and post-test (right) CT scans for Chin02

Figure 3 compares the uninjured facial structure before testing to the injured facial structure following high energy impact. The observed injury is a LeFort II fracture. Figure 4 shows non-normalized force-deflection plots used to determine the stiffness of the human chin for 1.6 m/s impacts. Initial stiffnesses were calculated for the linear region between 20-80% of the peak force and displayed in Table 2. The average stiffness was found to be 470 N/mm.

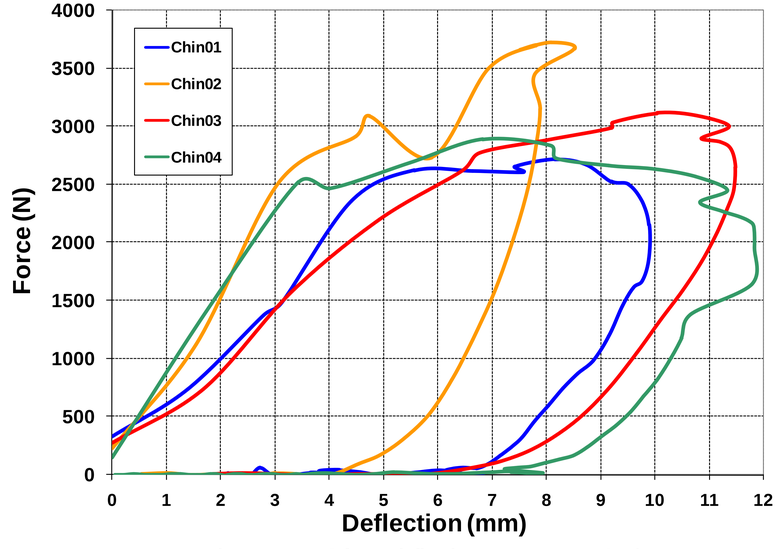

Figure 4. PMHS force-deflection responses - 1.6 m/sec

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

[1] Karlson, T.A., "The Incidence of Hospital-Treated Facial Injuries from Vehicles", The Journal of Trauma, Vol. 22 (4), April 1982, 303-310.

[2] Hopper, R.H., McElhaney, J.H., Myers, B.S. (1994) "Mandibular and Basilar Skull Fracture Tolerance", Proc. 38th Stapp Car Crash Conference, Society of Automotive Engineers, Warrendale, PA.

[3] Huelke, D. F., "Facial Injuries in Automobile Crashes", Journal of Oral and Maxillofacial Surgery, Vol. 41, April 1983, 241-244.

[4] Association for the Advancement of Automotive Medicine, "The Abbreviated Injury Scale, Des Plaines, Illinois, 1990.