



Development of a Headform to Evaluate Mouthguards

Chris Withnall, PE
Biokinetics and Associates Ltd.

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Do mouthguards prevent concussion?

- Stenger *et al* (JADA 1964): 5 American college football players, X-rays showed distraction of mandibular condyles from fossae with a mouthguard worn
- Hickey *et al* (JADA 1967): chin impacts to embalmed cadaver heads fixed in place
- McCrory (BJSM 2001): “neuro-mythology”, “no convincing evidence”
- Proponents: mouthguard manufacturers and dental practitioners

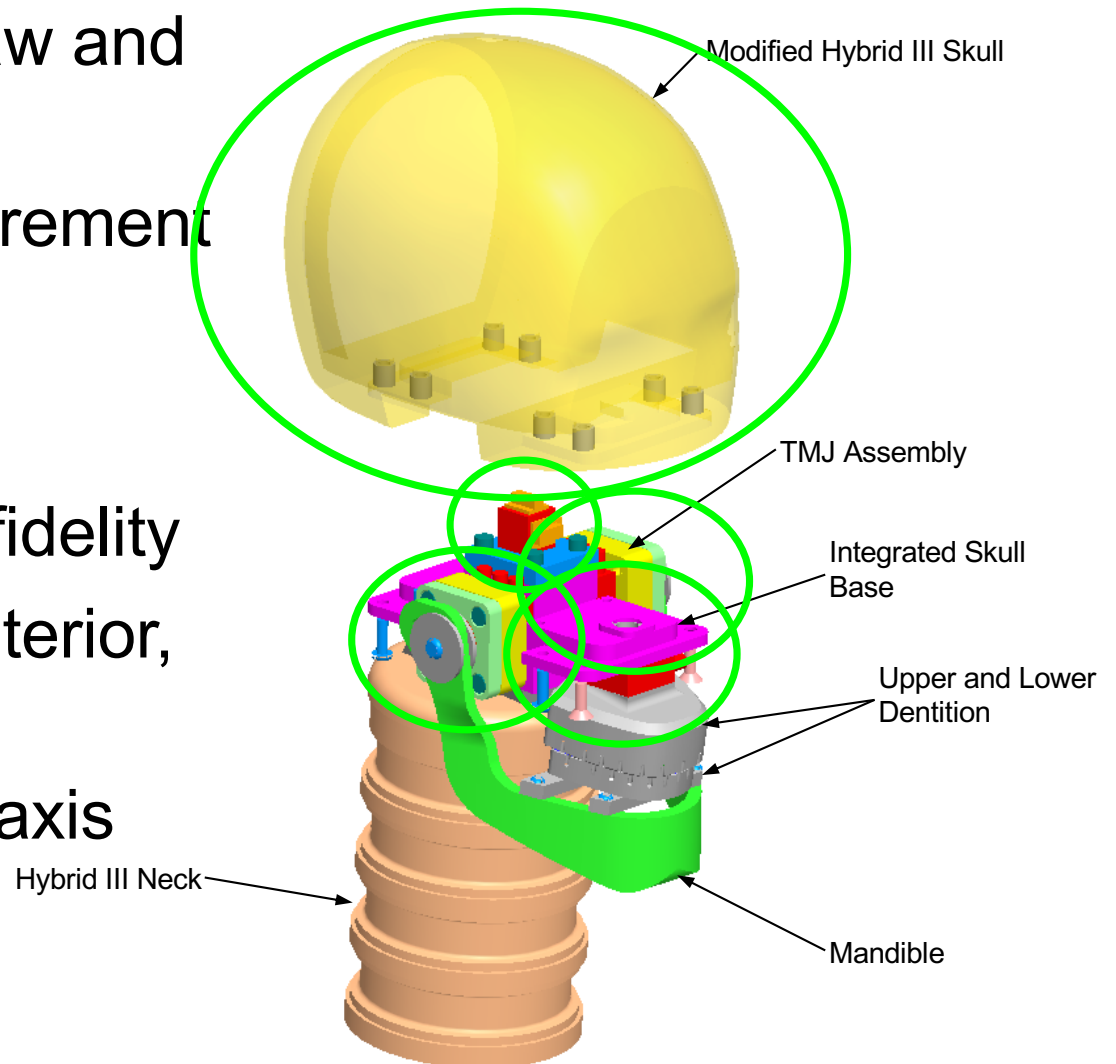


Objective: Headform to assess mouthguards

- Force-sensing jaw
NFL: load path from chinstrap and facemask
- Biomechanics
WSU cadaver tests – Matt Craig (Ph.D. candidate)
Impact force vs. chin displacement
- Design
Existing headform
Anthropometry, dentition
Instrumentation, space, biofidelity, robustness

Concept

- Remove Hybrid III jaw and skull floor
- Triaxial force measurement
TMJ
upper dentition
- Jaw articulation, biofidelity
medial, lateral, anterior,
inferior
- Head kinematics (3-axis
accelerometer)





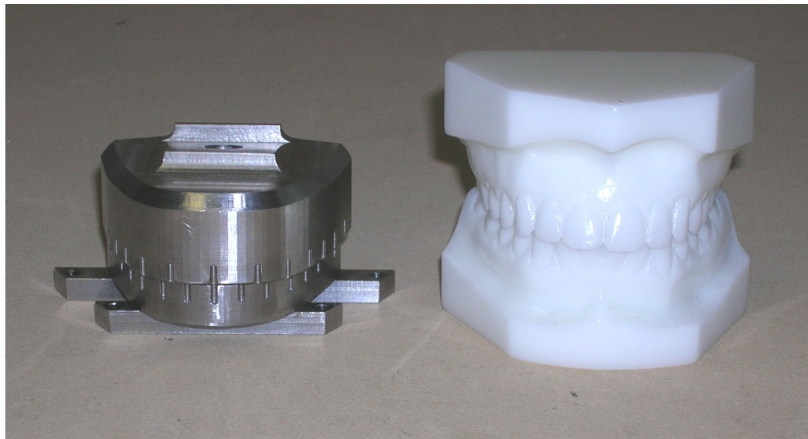
Mandible Anthropometry

- Geometry
 - HUMOS (human model for safety) car occupant model
 - Dragulescu et al (2002) Modeling and Dynamic Study of Human Mandible
- TMJ location
 - HyIII bony landmarks, anatomy texts
- General profile
 - NOCSAE headform, UMTRI skeletal model



Dentition

- 50th% dentition model does not exist
- Digitized dental model of *ideal dentition*
- CNC machined from stainless steel
- Verified to fit adult mouthguards



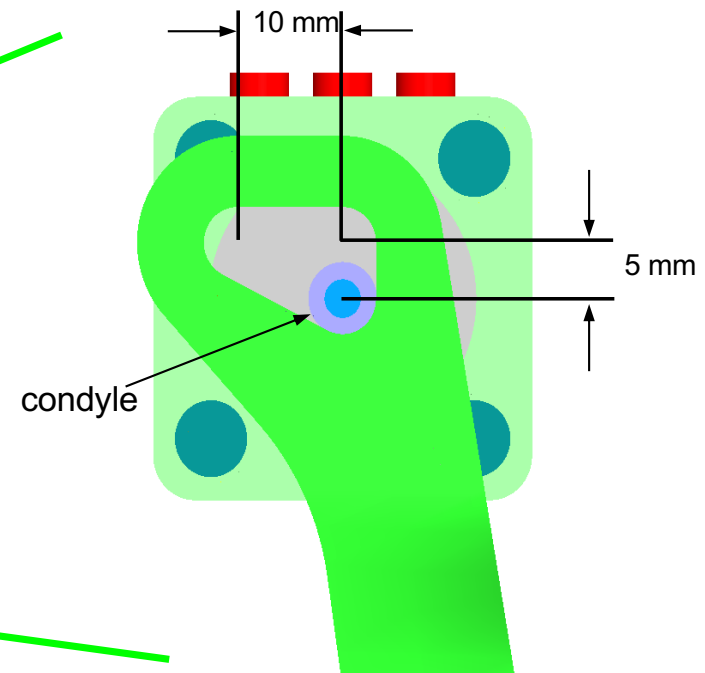
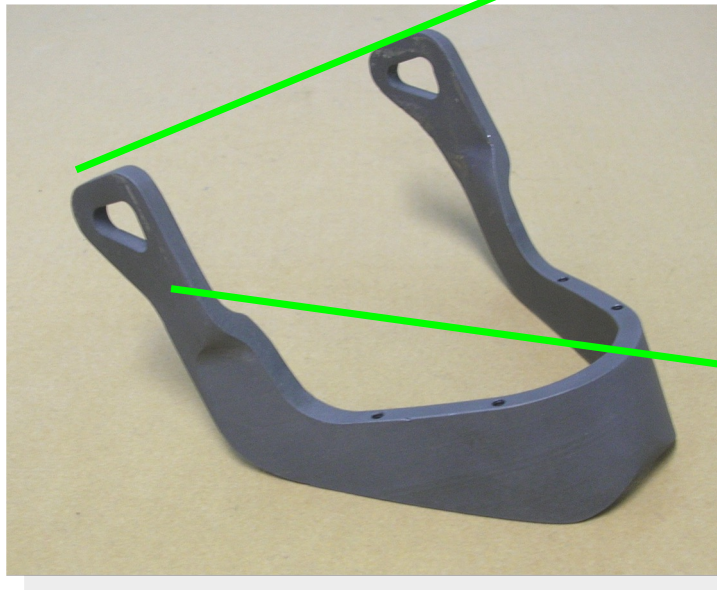


TMJ: Range of Motion

- Neutral pos'n (clenched teeth), condylar process supported posteriorly and superiorly
- 10-12 mm anterior, 5-6 mm inferior, 0.75 mm medial and lateral (Sturdevant 4th edition)
- At rest, jaw descends 3.5-4.8 mm without hinging: necessary space for mouthguard
- Prototype jaw rigid: all motion is at condyle

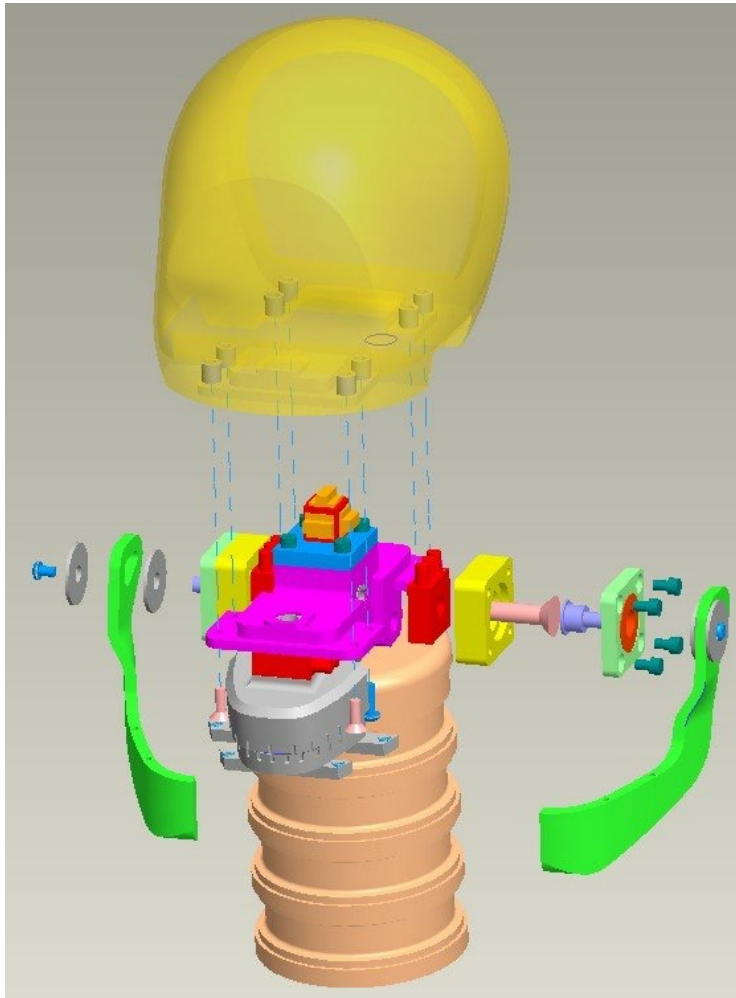
TMJ: Design

- Triangular slot
- TMJ is a pin cast into an elastomeric ring

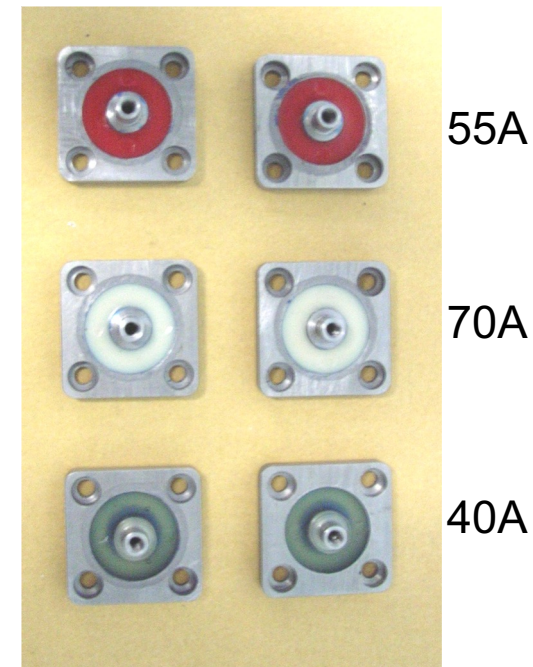




TMJ: Design



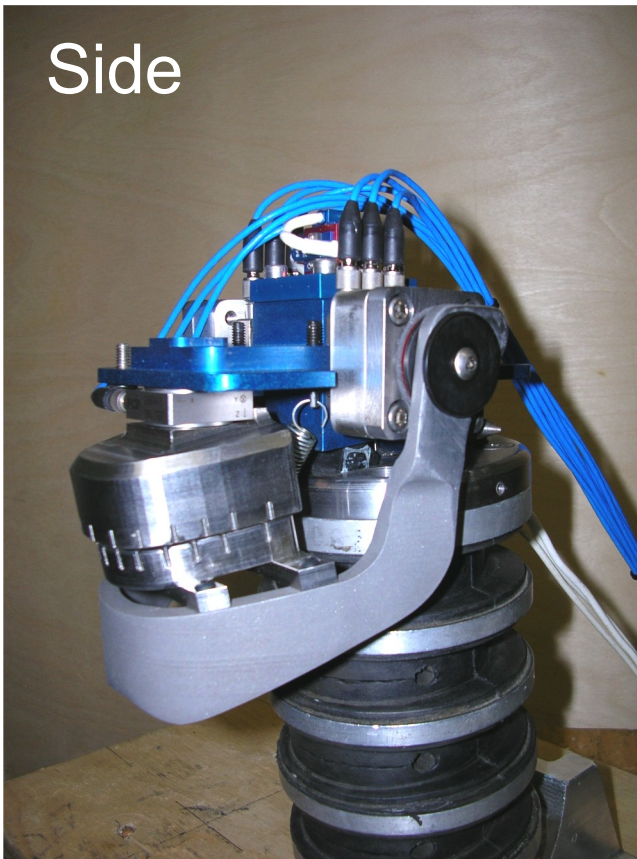
- 3 durometers to tune TMJ response





Prototype

Side

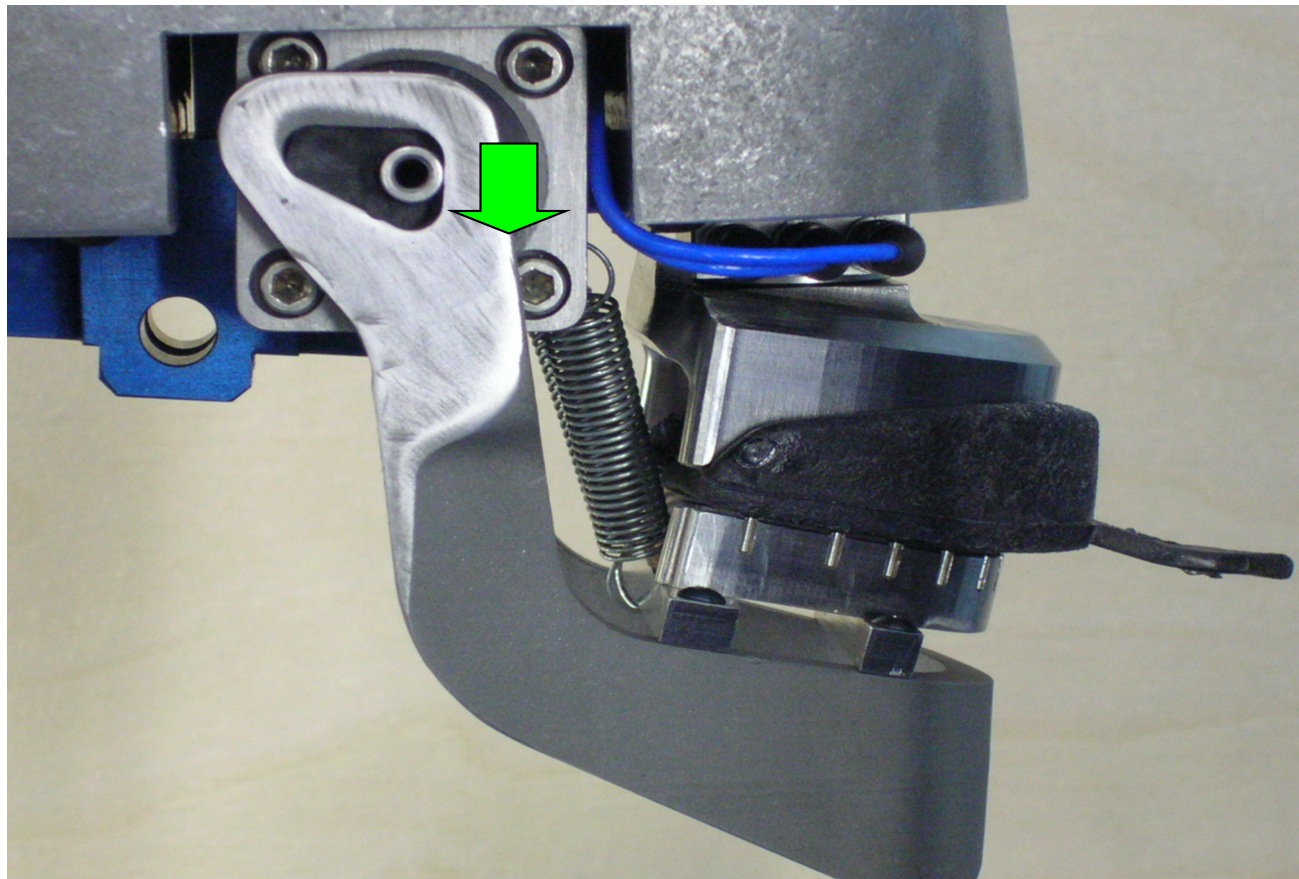


Front

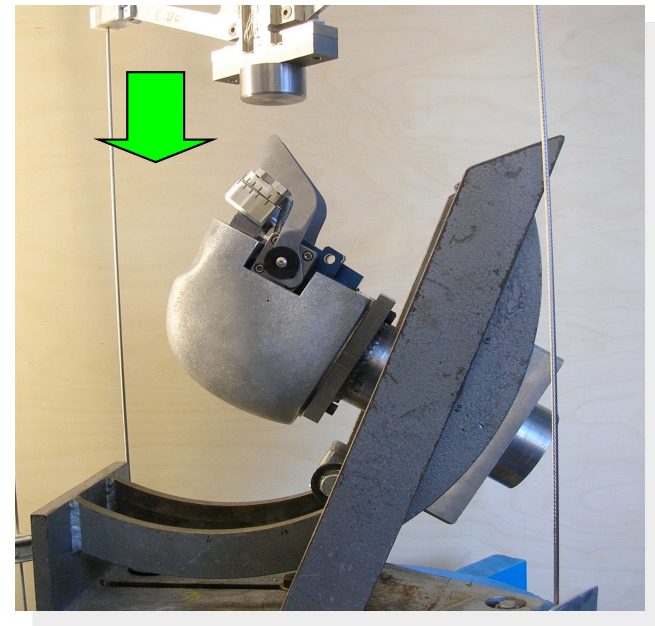
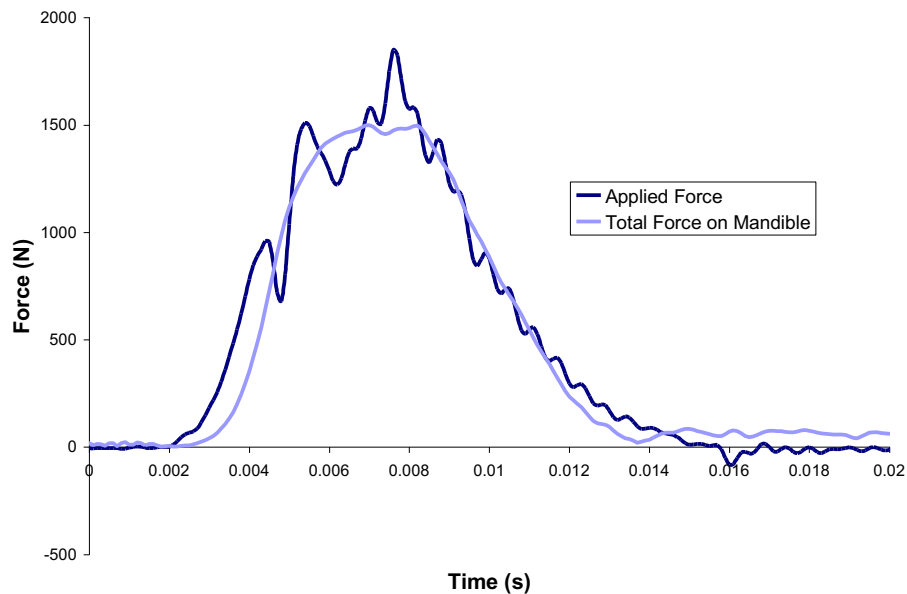
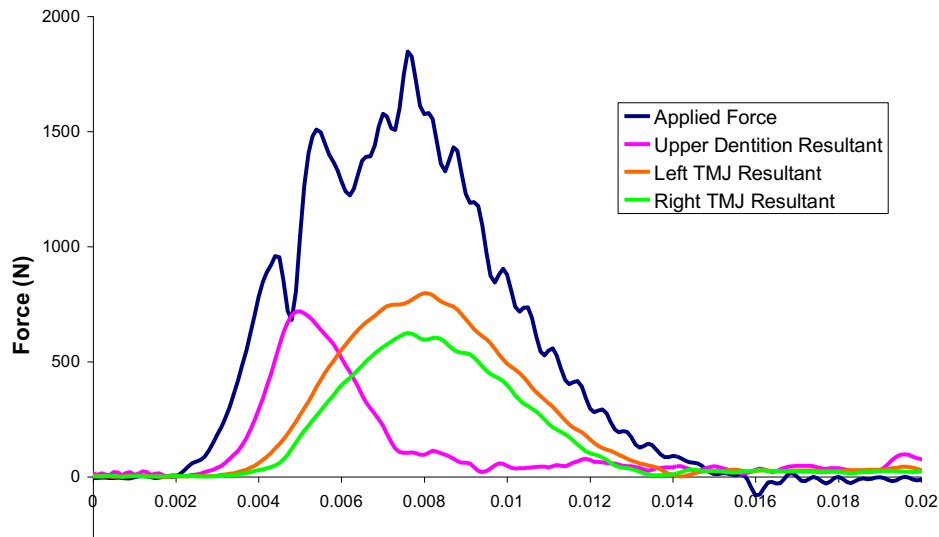




Prototype: condyle with mouthguard

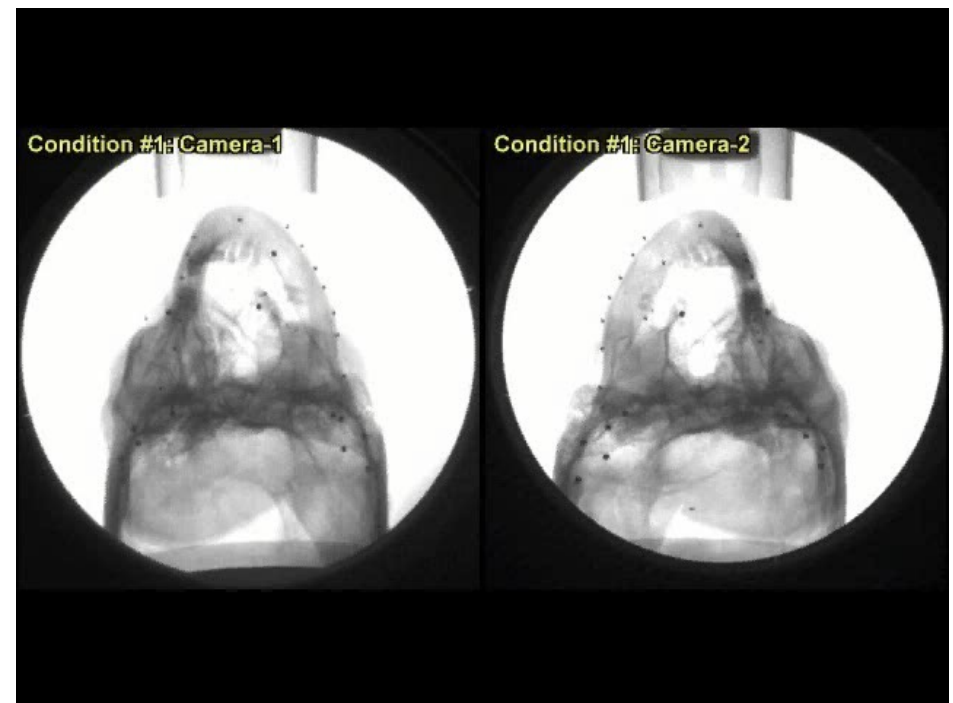


Force Measurement Confirmation



Validation Testing

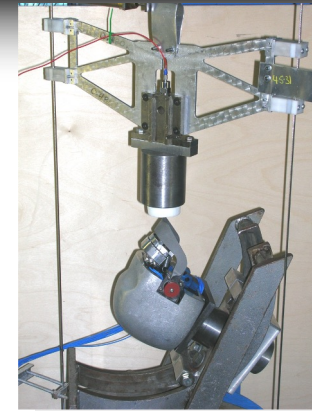
- WSU draft corridors
- Falling mass
 - 2.8 kg (0.3, 0.4, 0.5 m)
 - 5.2 kg (0.4 m, 0.5 m)
- Force, chin displacement, condyle displacement
- Oriented chin-condyle vertical



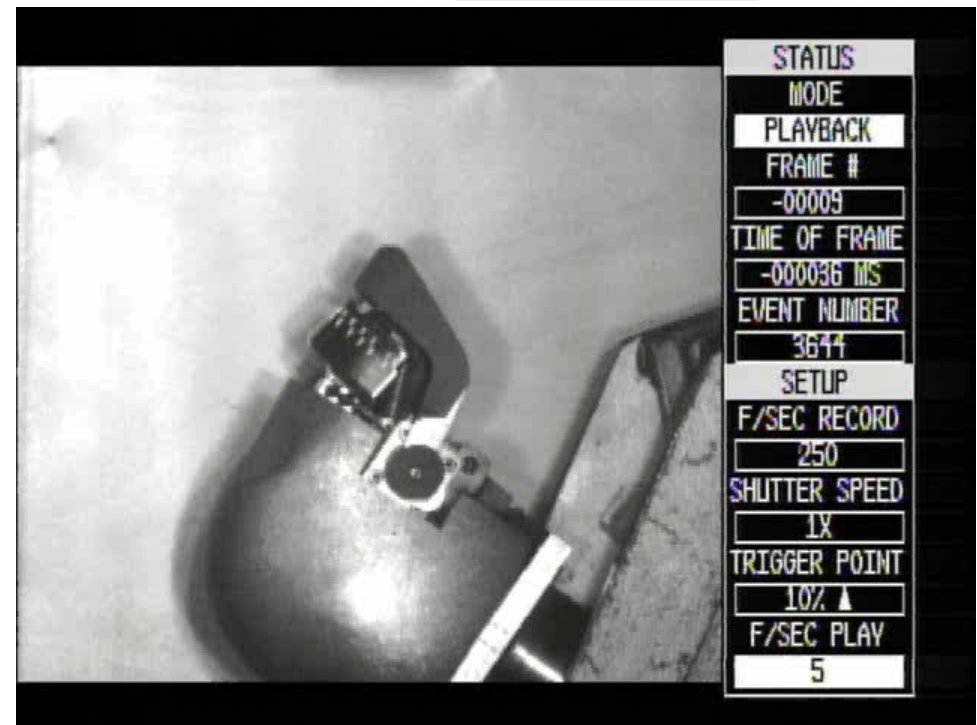


Validation Testing

- 5.2 kg, 0.5 m (25 J),
40A durometer



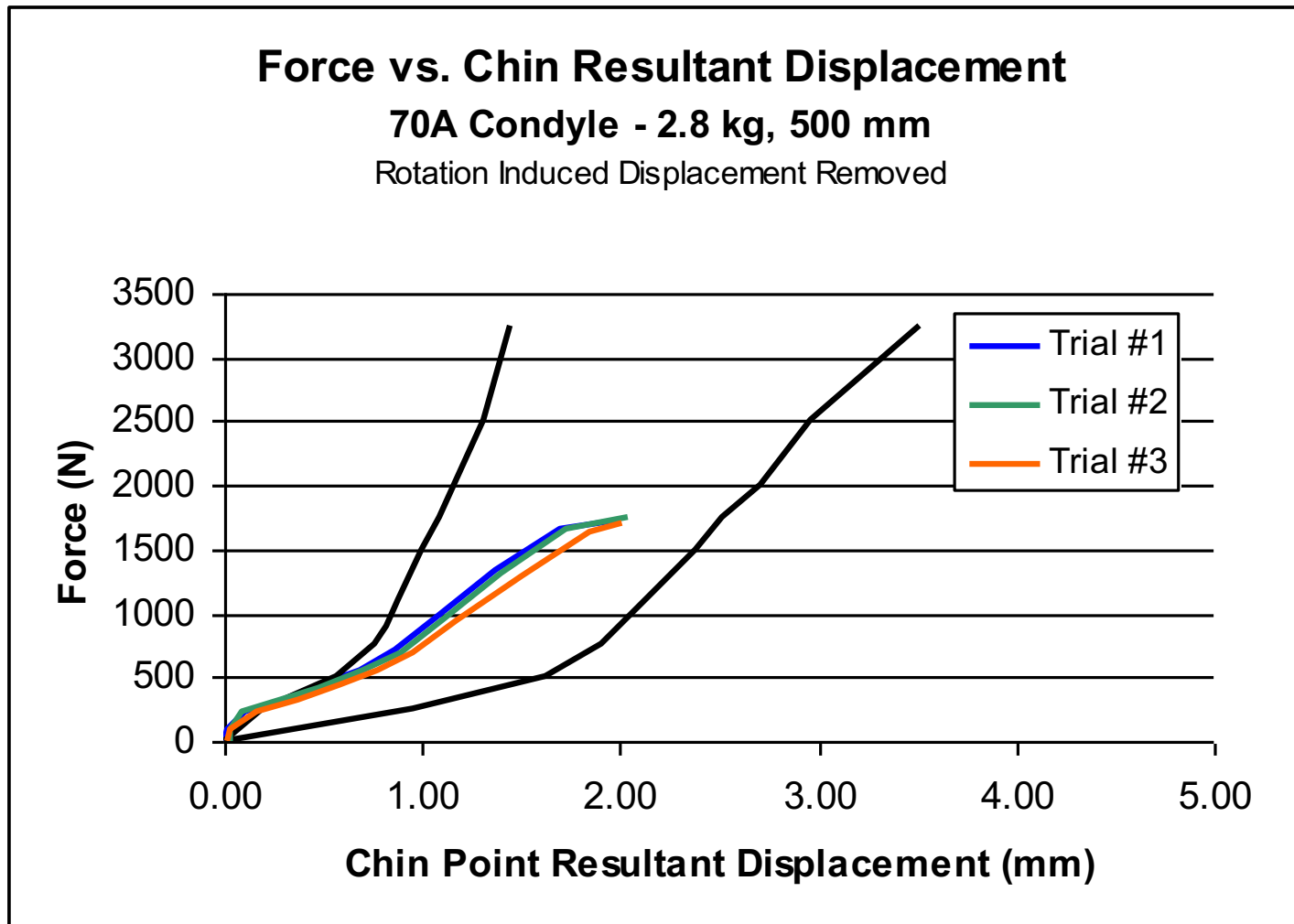
skin



no skin

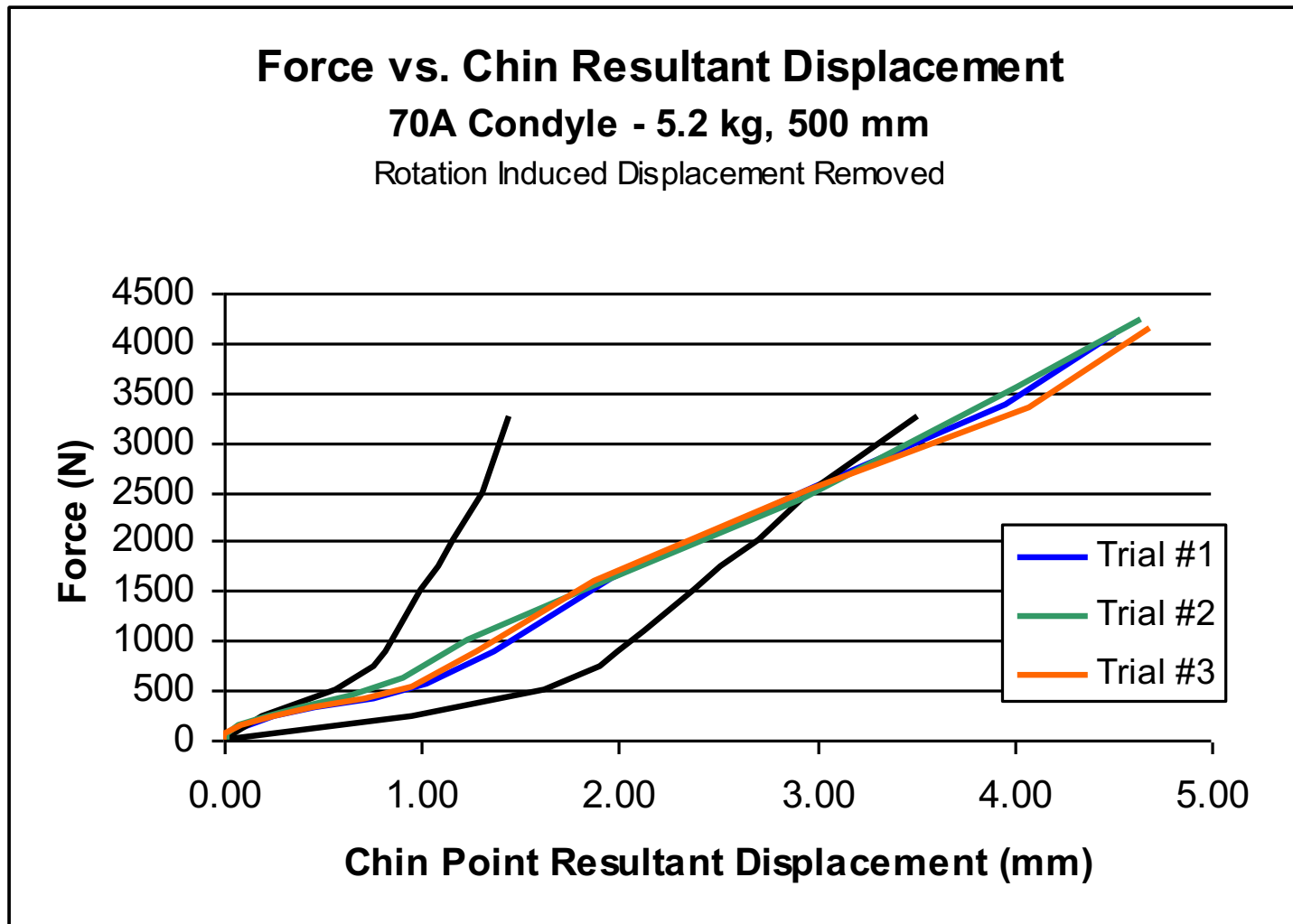


Chin Resultant Displacement (2.8 kg)





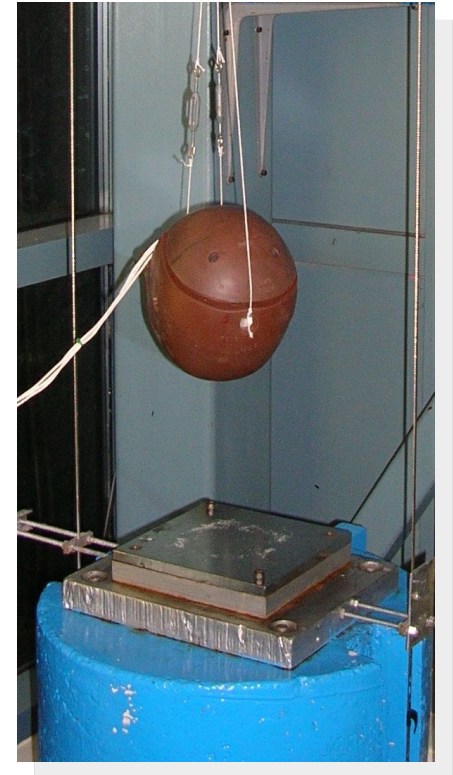
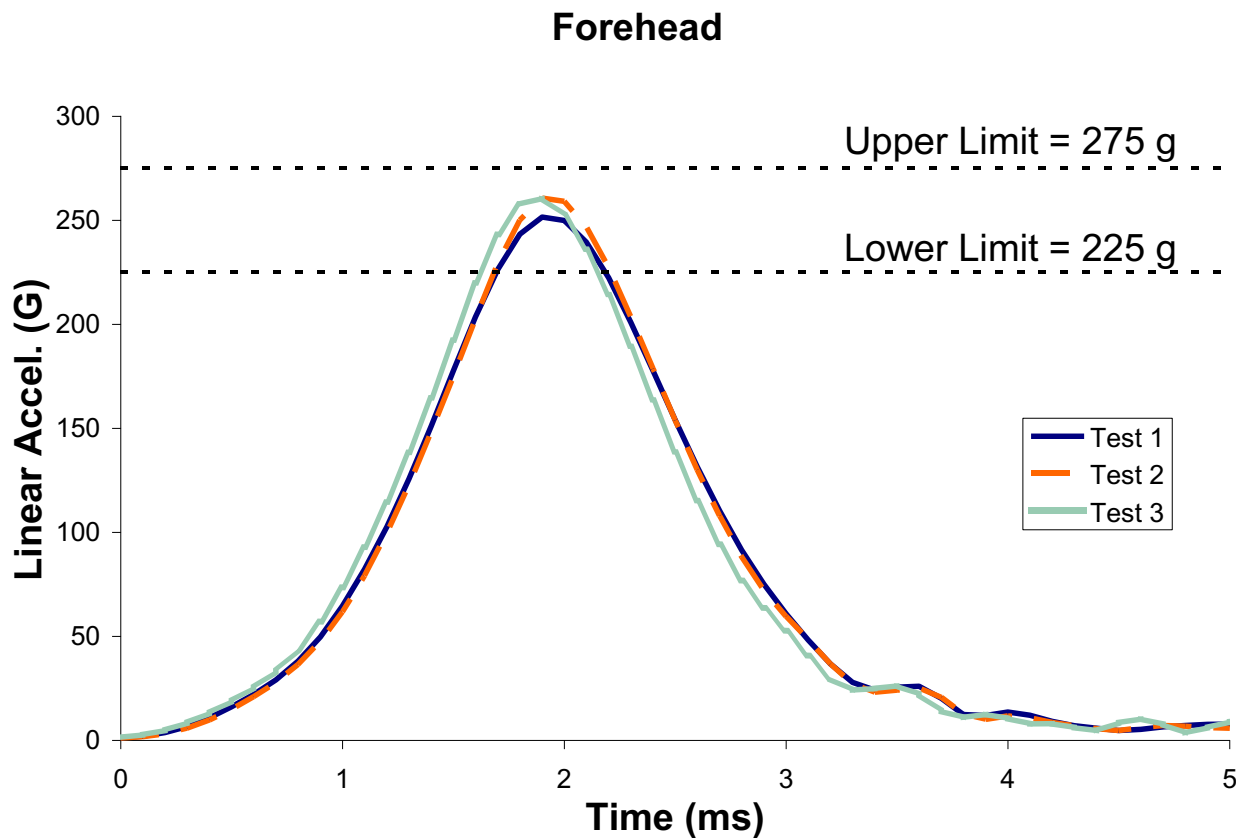
Chin Resultant Displacement (5.2 kg)





Head Impact Check

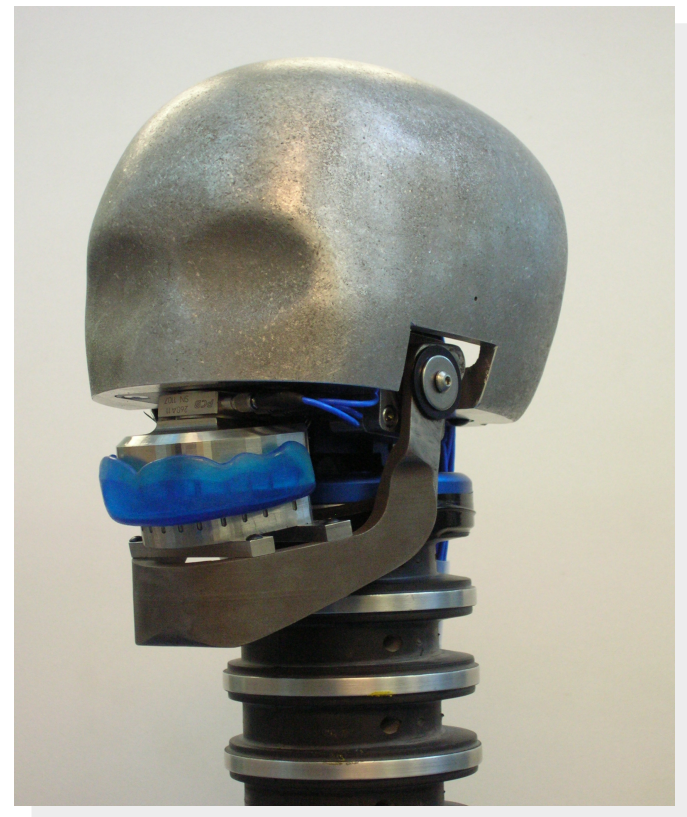
- SAE dynamic impact response





Preliminary Mouthguard Tests

- Headform sensitivity, durability, data quality
- Mouthguards
 - Off-the-shelf boil & bite
 - 5 models (incl. one bi-maxillary)
 - Compared to no mouthguard condition





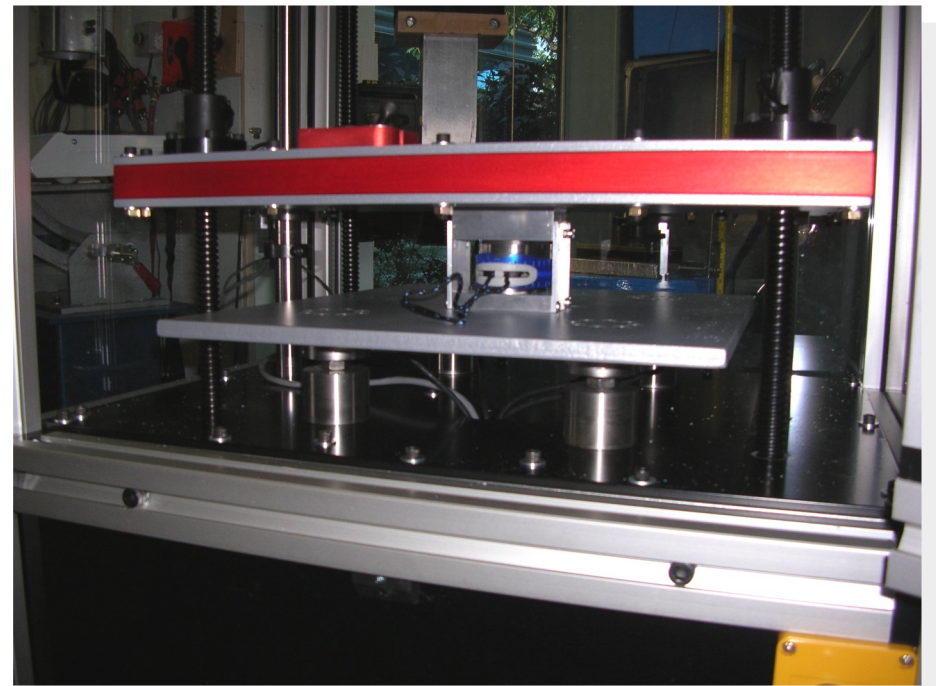
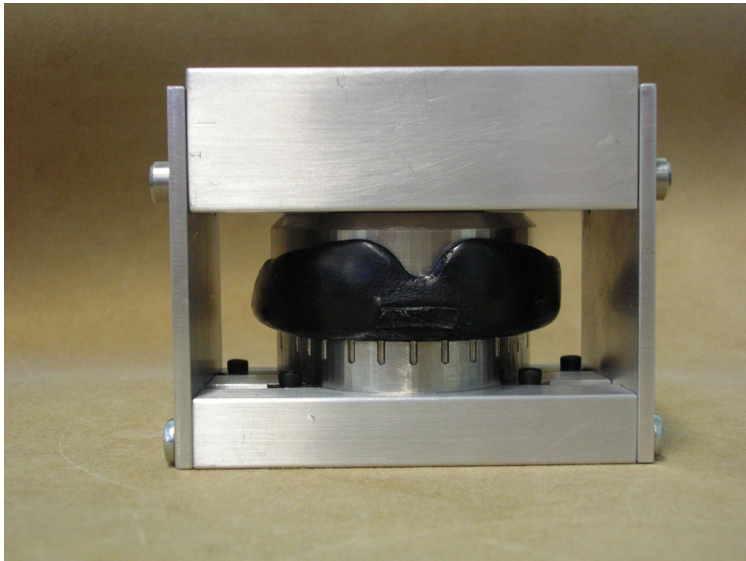
Preliminary Mouthguard Tests



Preliminary Mouthguard Tests

Forming guards

- Preheated dentition 37°C
- 150 N (gentle bite)
- 325 N (firm bite)



Preliminary Mouthguard Tests

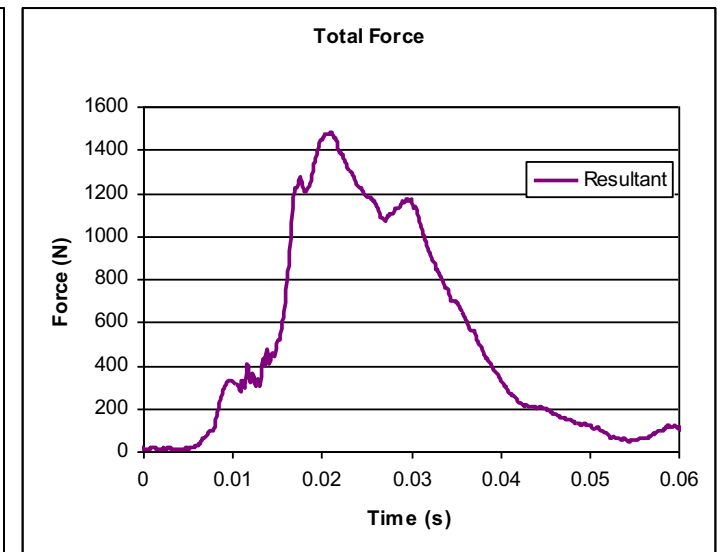
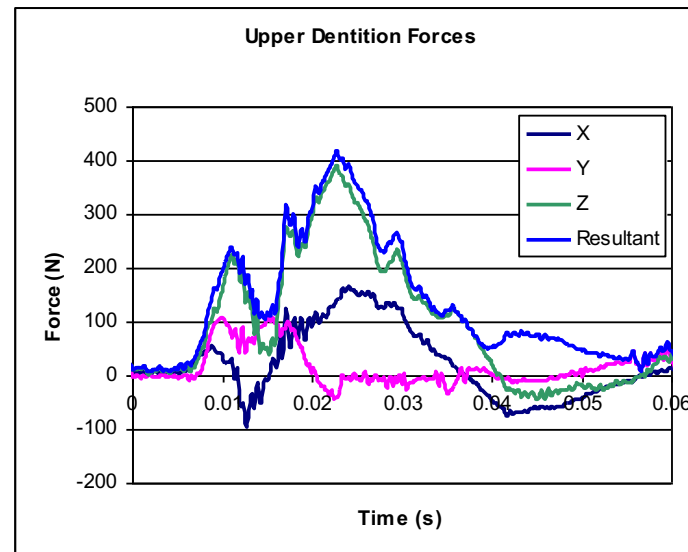
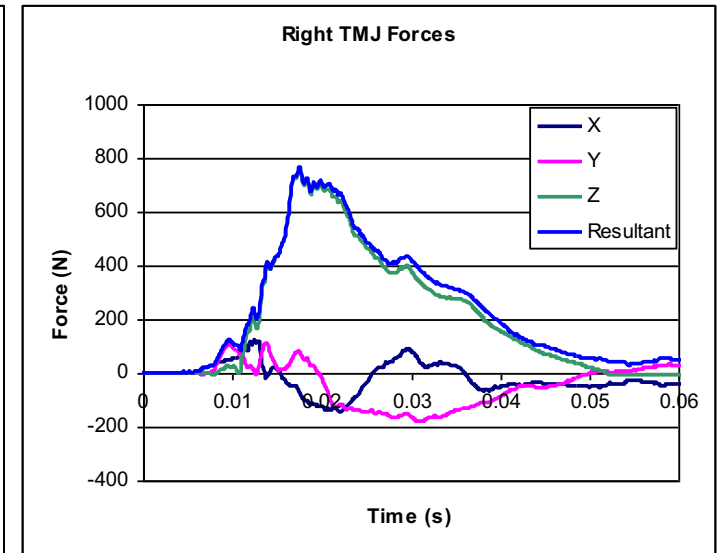
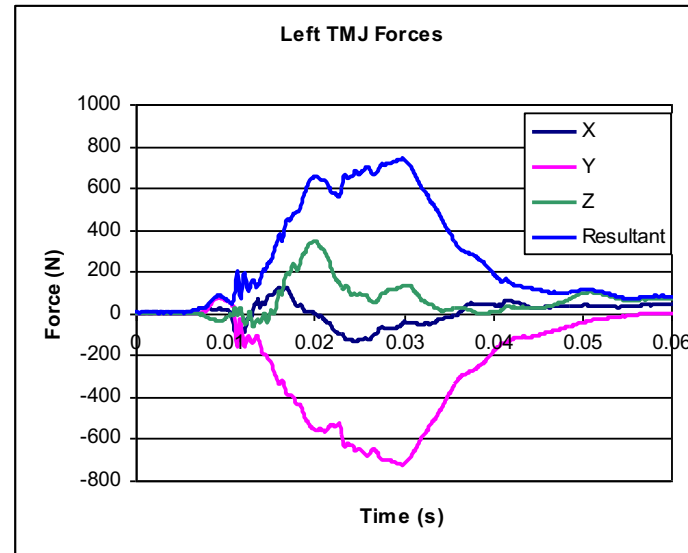
- Facemask, low oblique
- Headform mounted on linear impactor
- 6.7 m/s and 9.5 m/s
- Schutt AVC helmet
- Three hits/site, averaged
- Head A_{\max} , jaw F_{tot}





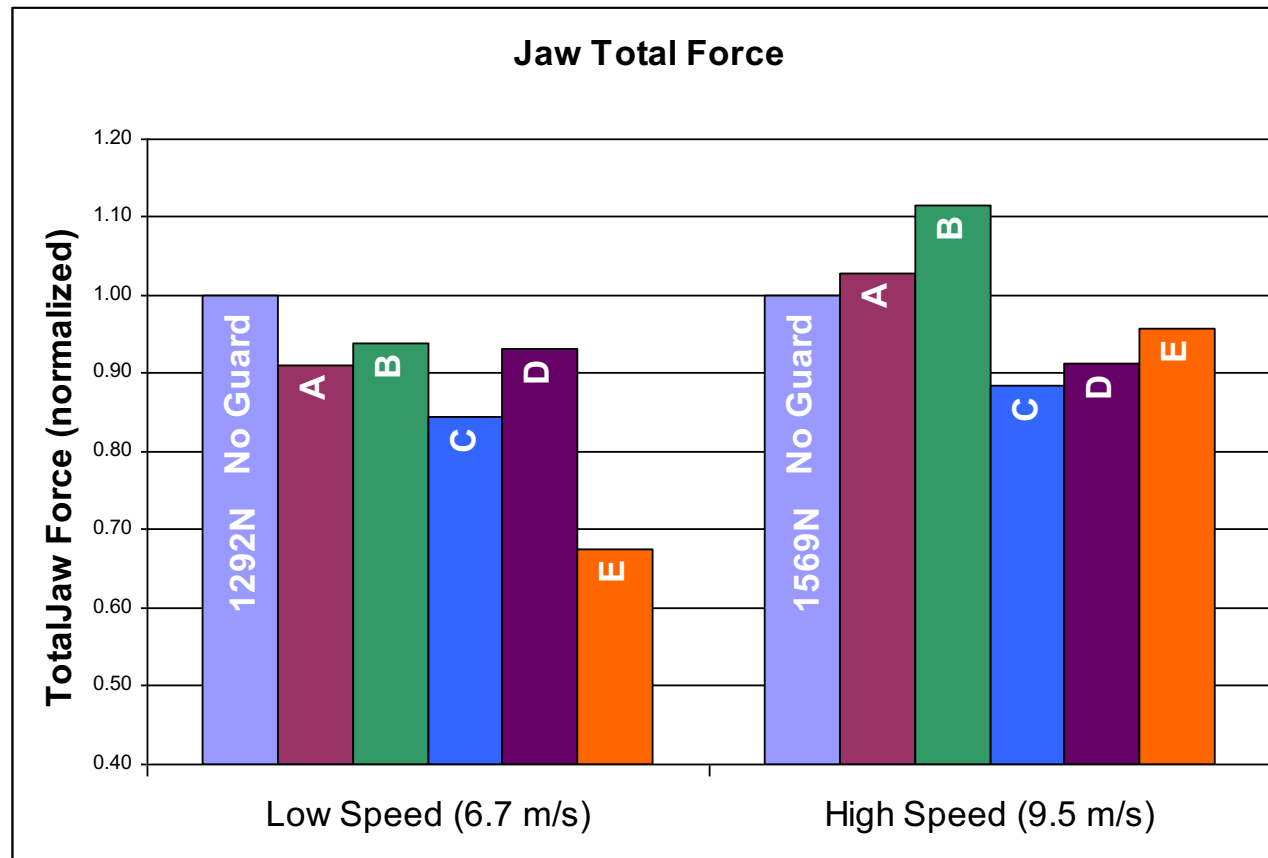
Preliminary Mouthguard Tests

- Total jaw force



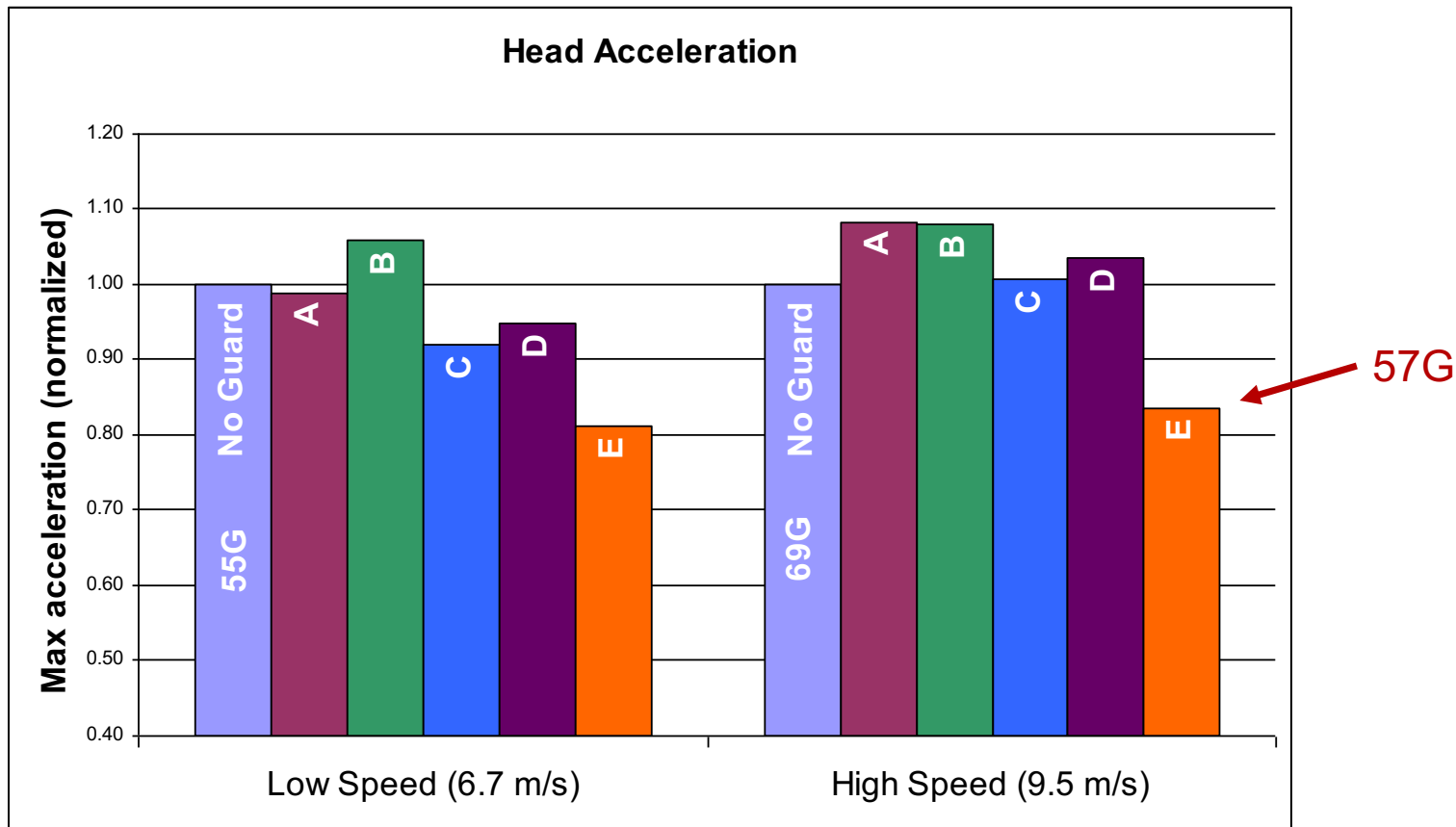


Preliminary Mouthguard Tests





Preliminary Mouthguard Tests





Preliminary Mouthguard Tests

Summary

- Up to 32% reduction in jaw force
- Up to 19% reduction in peak head acceleration
- Headform demonstrated sensitivity, ruggedness
- Further testing 2007



Future Considerations...

- Mouthguard models
 - Do they reduce TMJ force?
 - Do they affect head acceleration?
 - Boil and bite versus custom?



Questions?