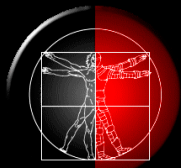
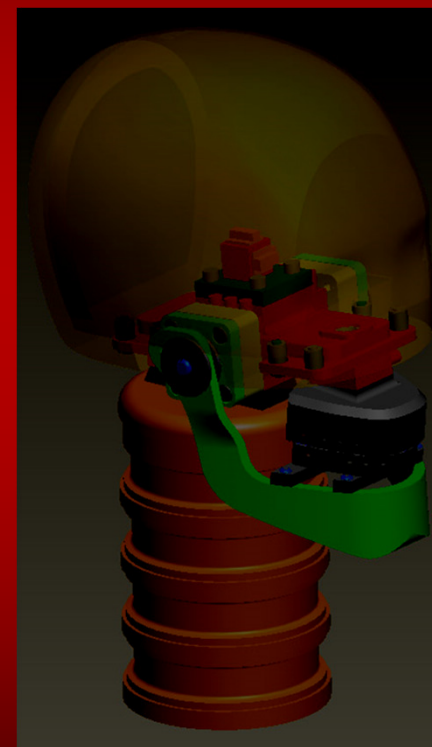


Development of a Headform with Articulating Mandible

by:
Christopher Withnall, PE

for:
ASTM Shirtsleeves

May 17, 2006
Toronto, ON



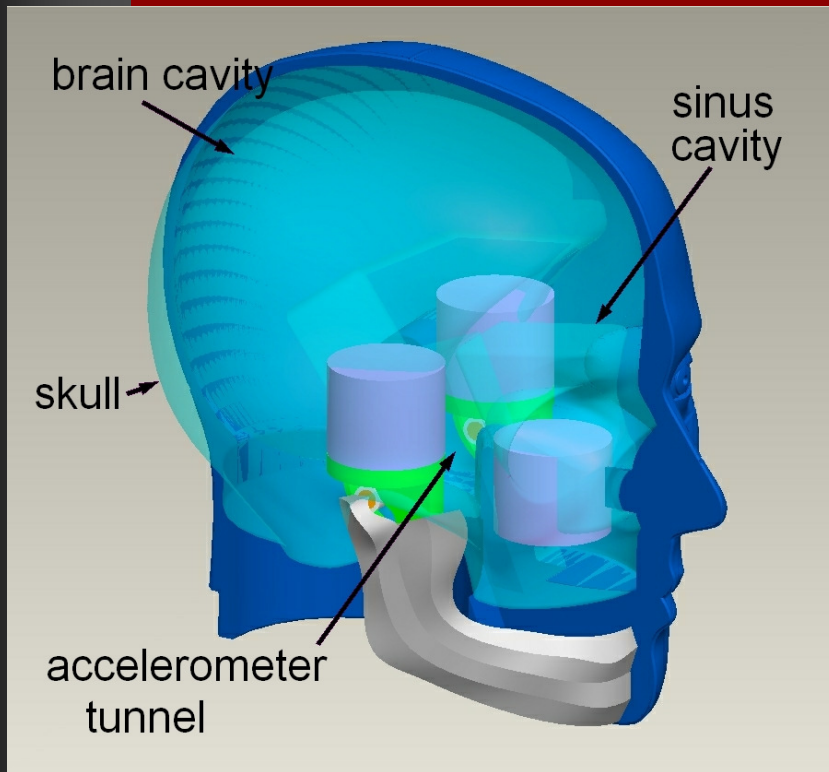
Objectives

- ▶ Force-sensing jaw
 - *NFL sponsors: football helmet chinstrap*
 - *Mouth-guards vs. concussion*
- ▶ Biomechanics
 - *WSU cadaver tests*
 - *Impact force vs. chin displacement*
- ▶ Design criteria
 - *Use existing headform*
 - *Proper anthropometry, dentition*
 - *Instrumentation, biofidelity, robustness*

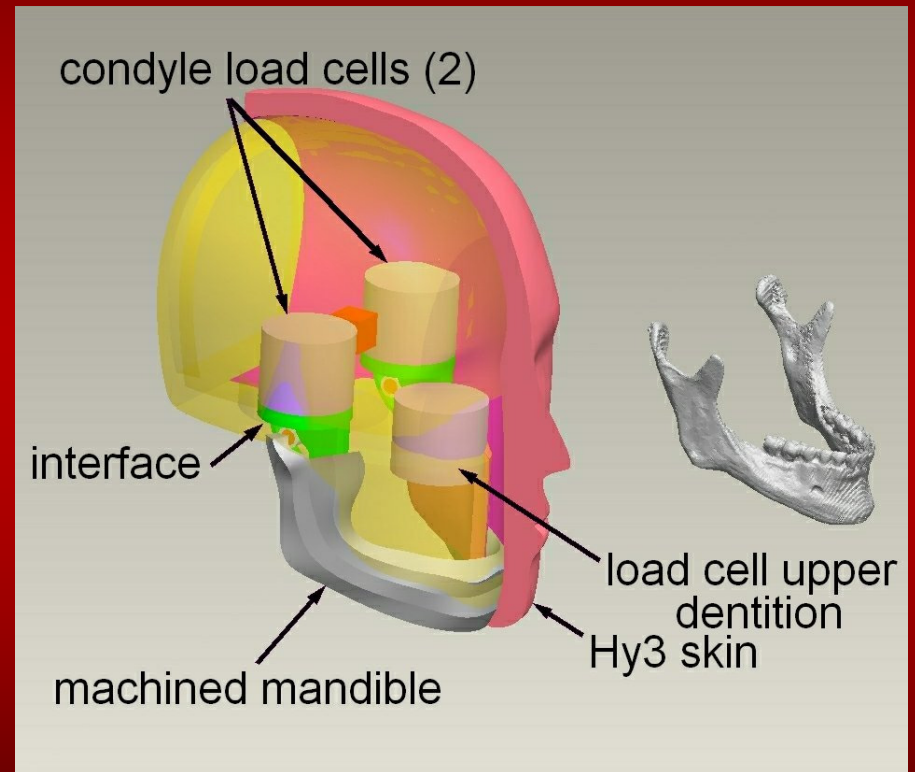


Headform Platform

NOCSAE (med)

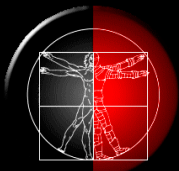
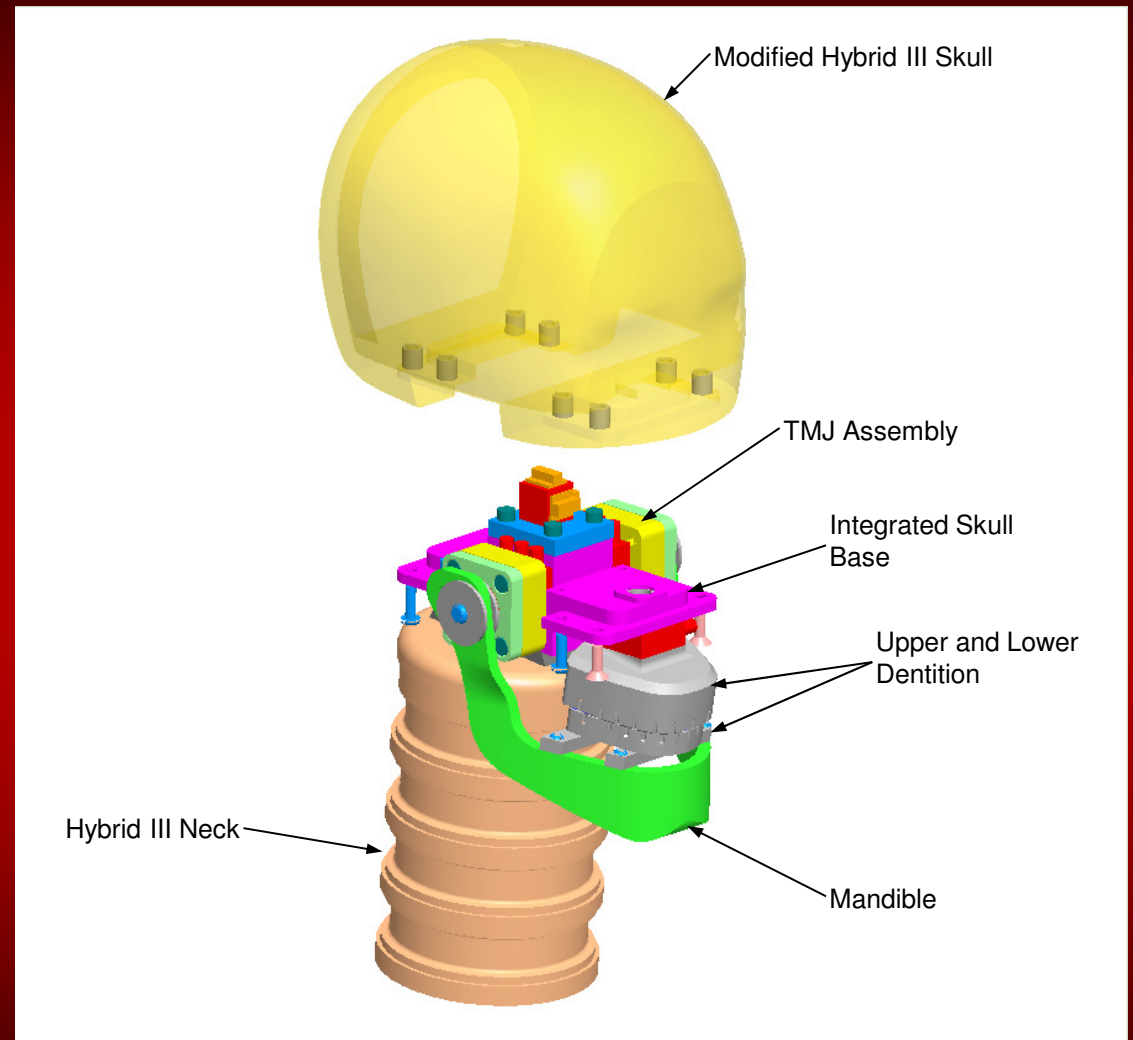


Hybrid III (50th%)



Concept

- *Remove Hy3 jaw and skull floor*
- *Triaxial force*
 - *L & R TMJ*
 - *Upper dentition*
- *Jaw Articulation*
 - *L & R*
 - *Forward*
 - *Downward*
- *TMJ bumper*
- *3-axis head acceleration*



Mandible Anthropometry

▶ Geometry

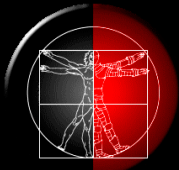
- *HUMOS (human model for safety) car occupant model*
- *Dragulescu et al (2002) Modeling and Dynamic Study of Human Mandible*

▶ TMJ location

- *Hy3 bony landmarks, anatomy texts*

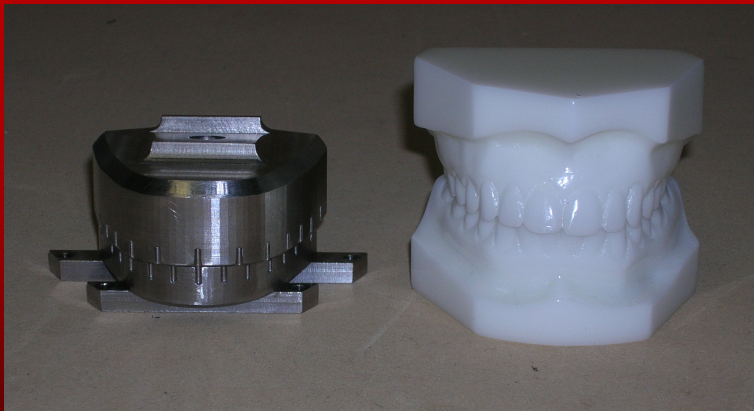
▶ General profile

- *NOCSAE headform, UMTRI skeletal model*



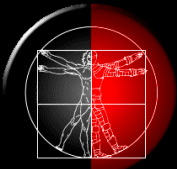
Dentition

- ▶ Ideal 50th% dentition model does not exist.
- ▶ Digitized dental model of ideal dentition.
- ▶ CNC machined SS
- ▶ Verified to fit adult mouthguards.



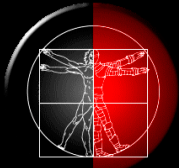
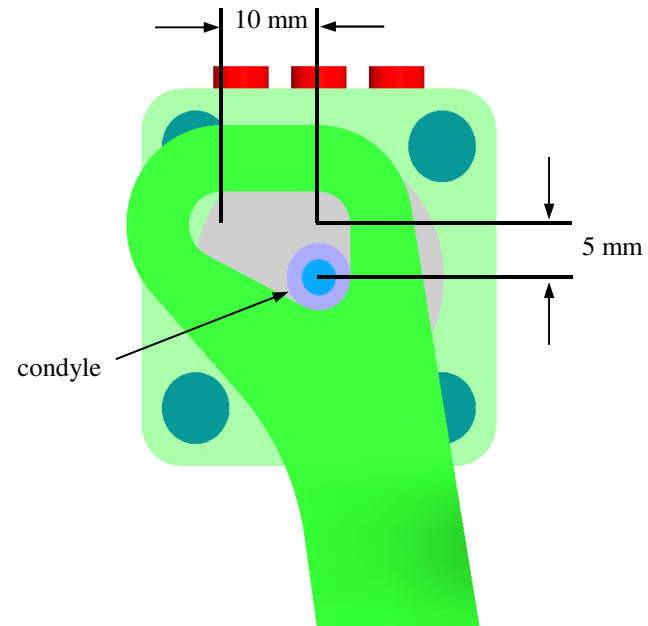
TMJ: Range of Motion

- ▶ 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.
- ▶ Presume jaw rigid: all motion at condyle.

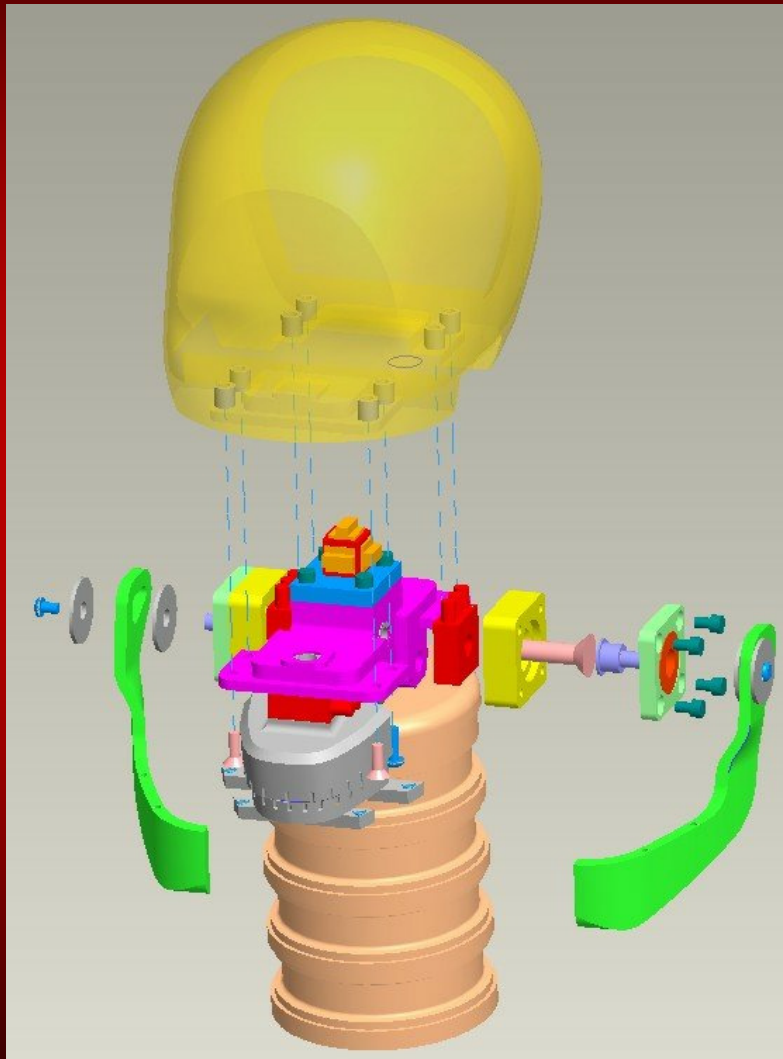


TMJ: Design

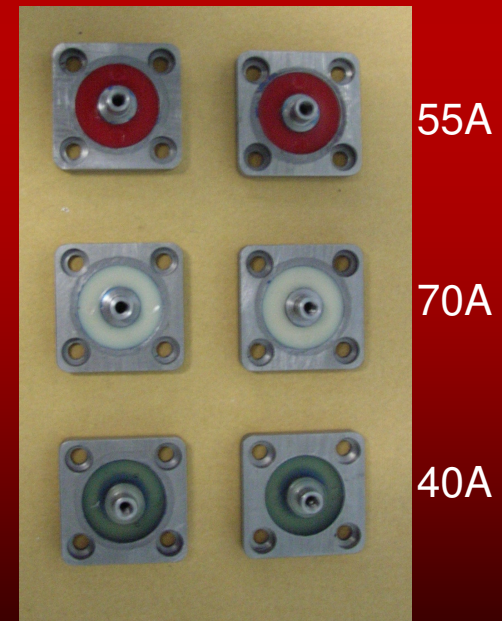
- ▶ Triangular slot
- ▶ TMJ is a pin cast into an elastomeric donut.



TMJ: Design



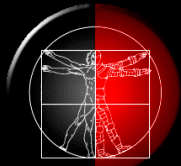
- *3 experimental durometers*
- *Target 2.5 mm @ 1000N*



Prototype



Biokinetics



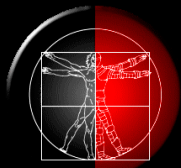
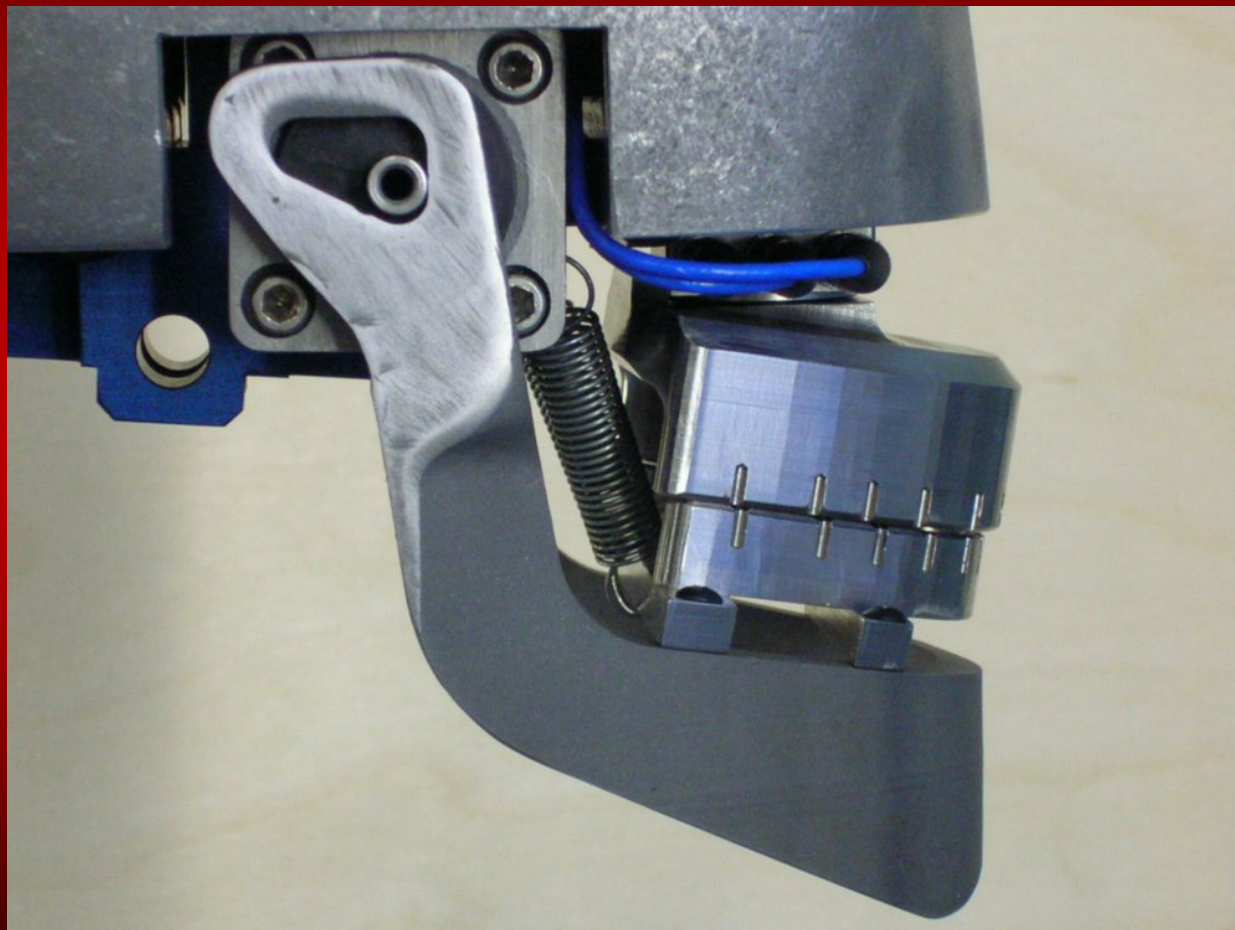
Prototype



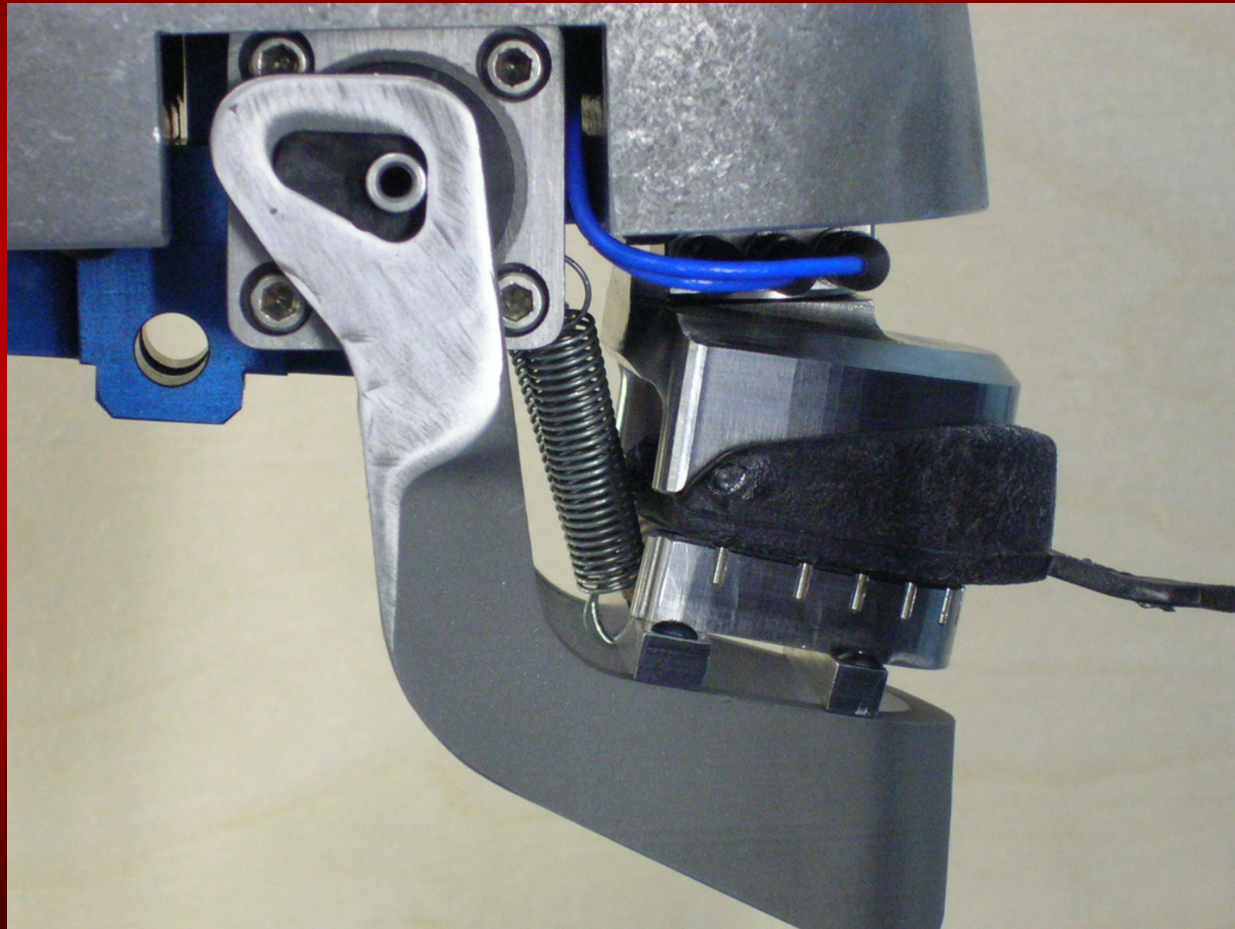
Biokinetics



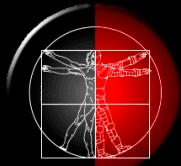
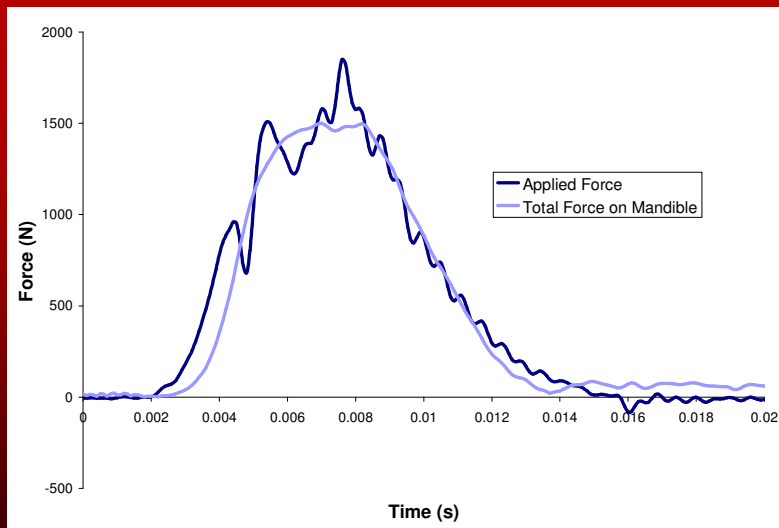
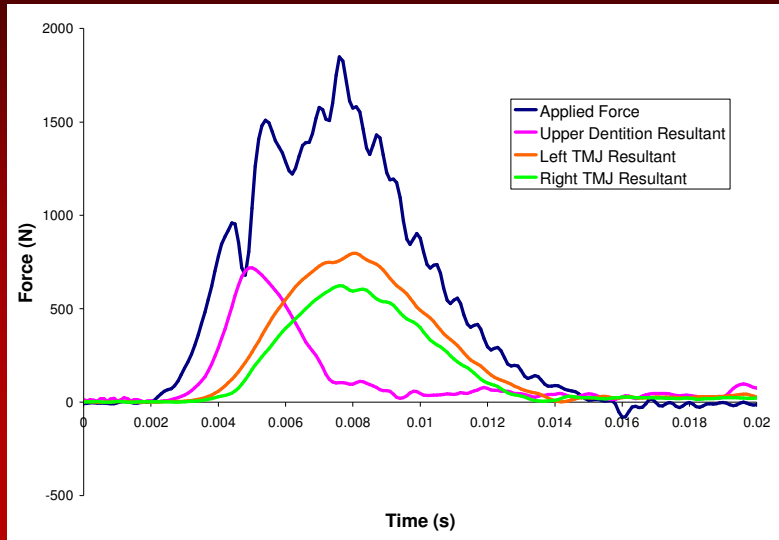
Prototype: condyle neutral



Prototype: condyle with mouthguard

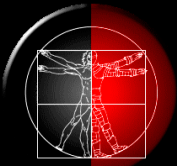
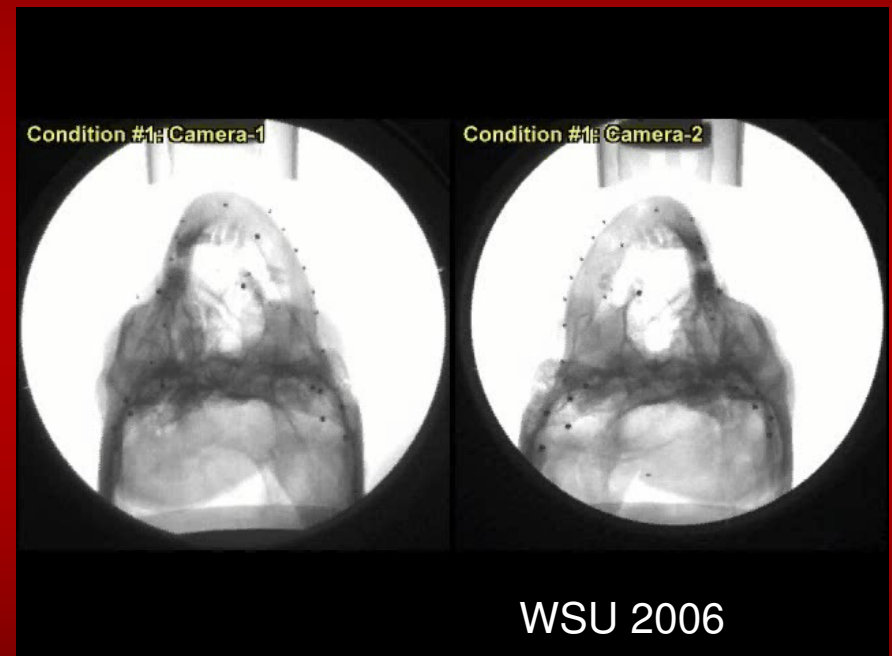


Force sensor check



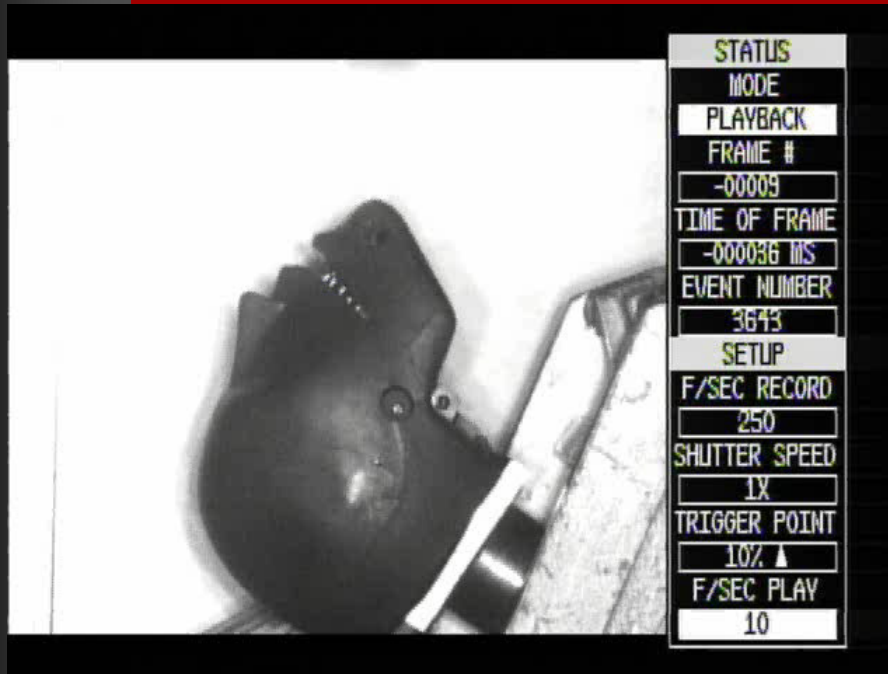
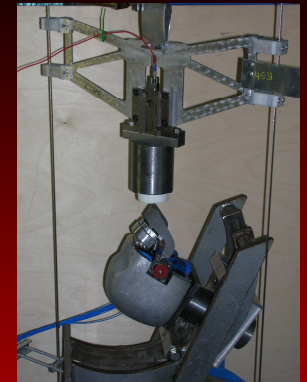
Validation Testing

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

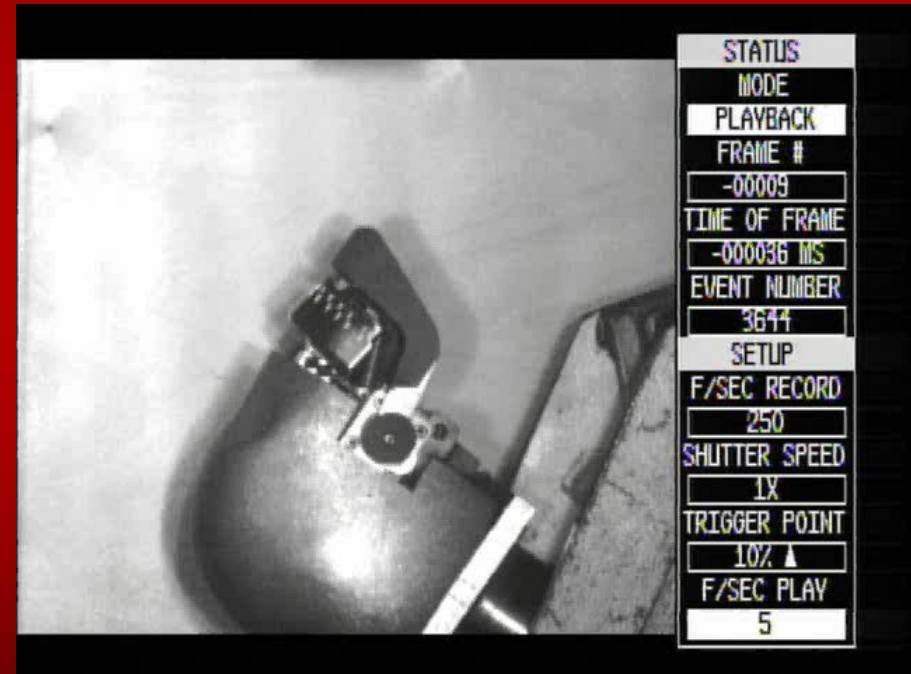


Validation Testing

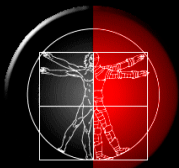
- 5.2 kg, 0.5 m (25 J),
40A durometer



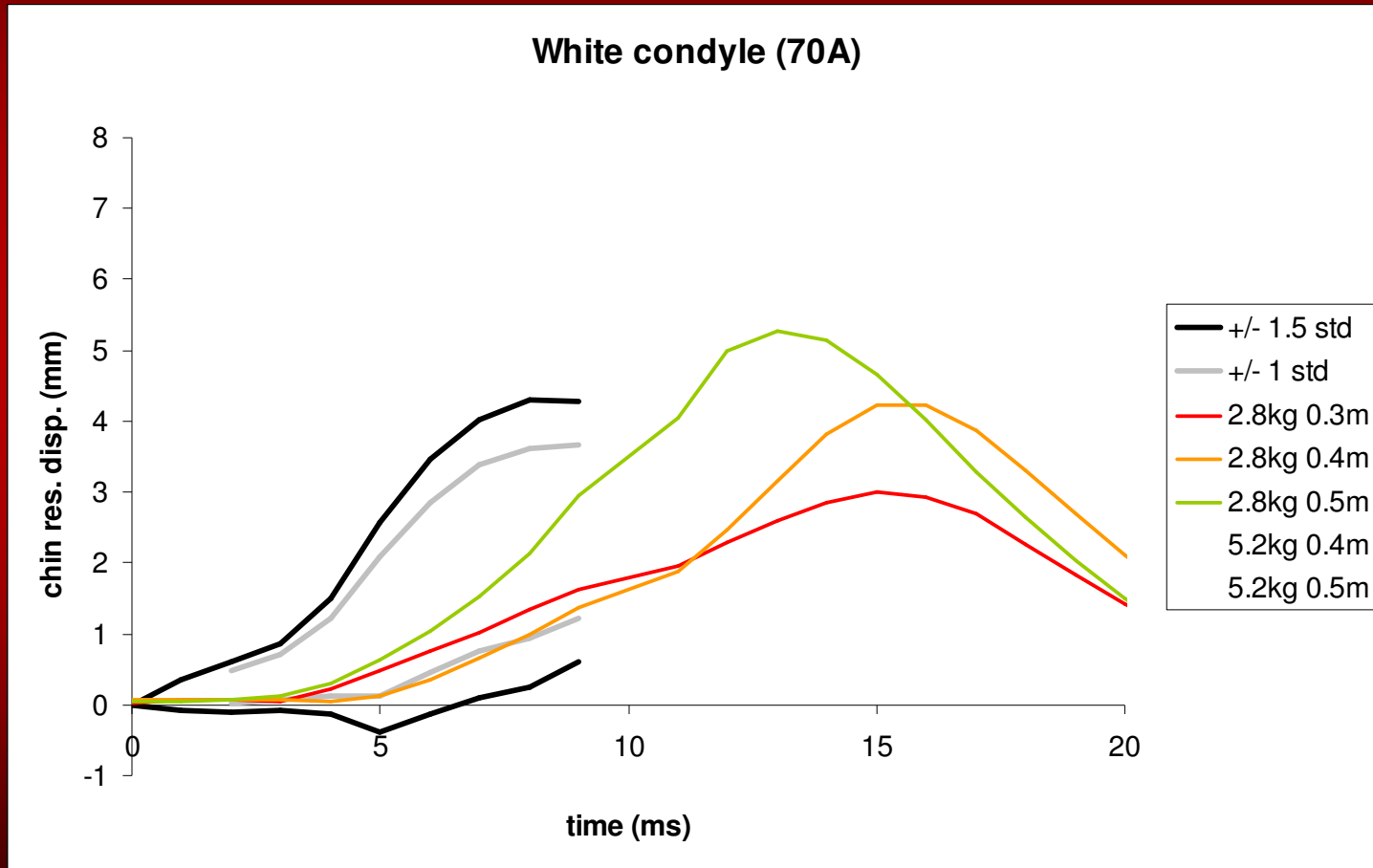
skin



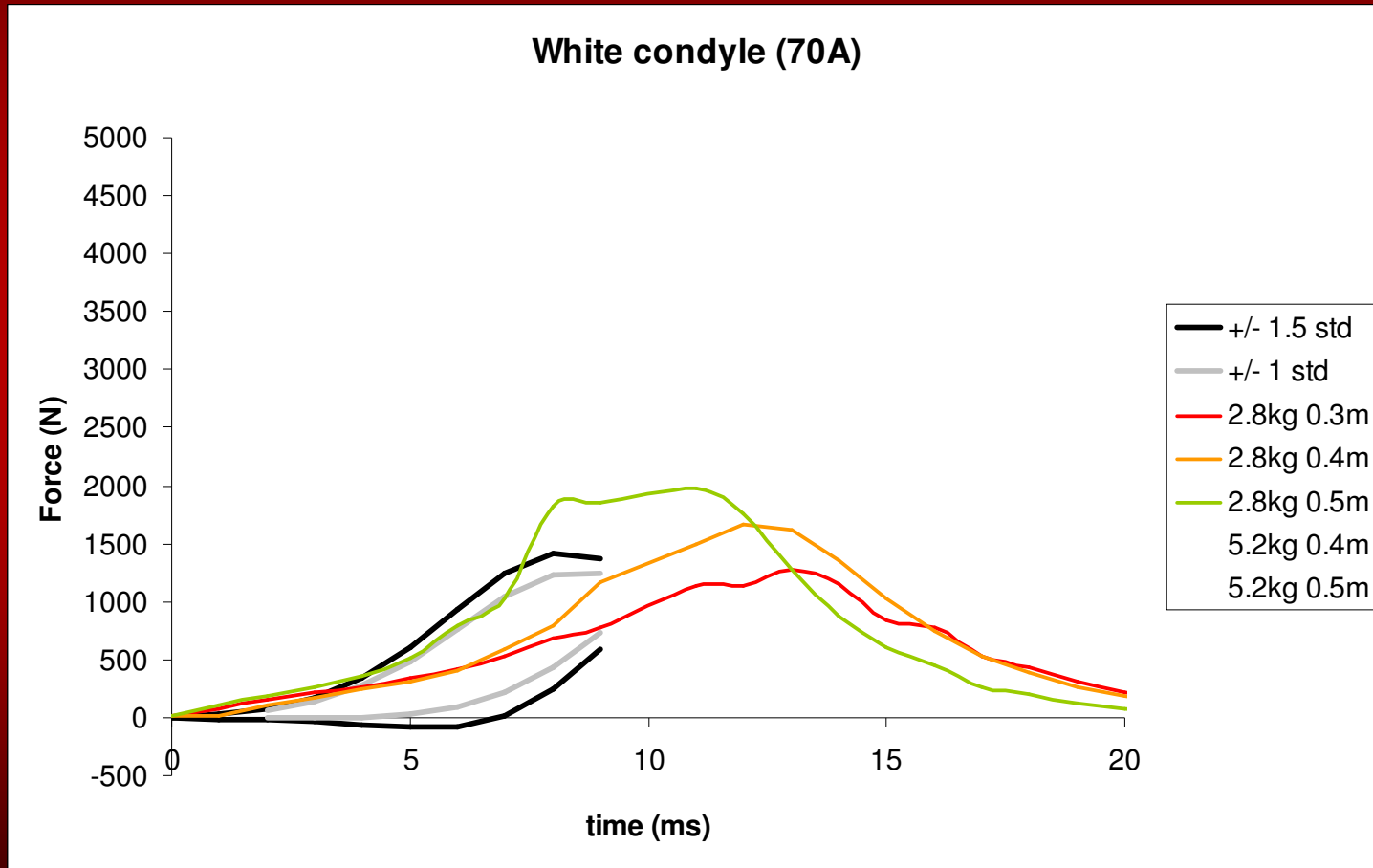
no skin



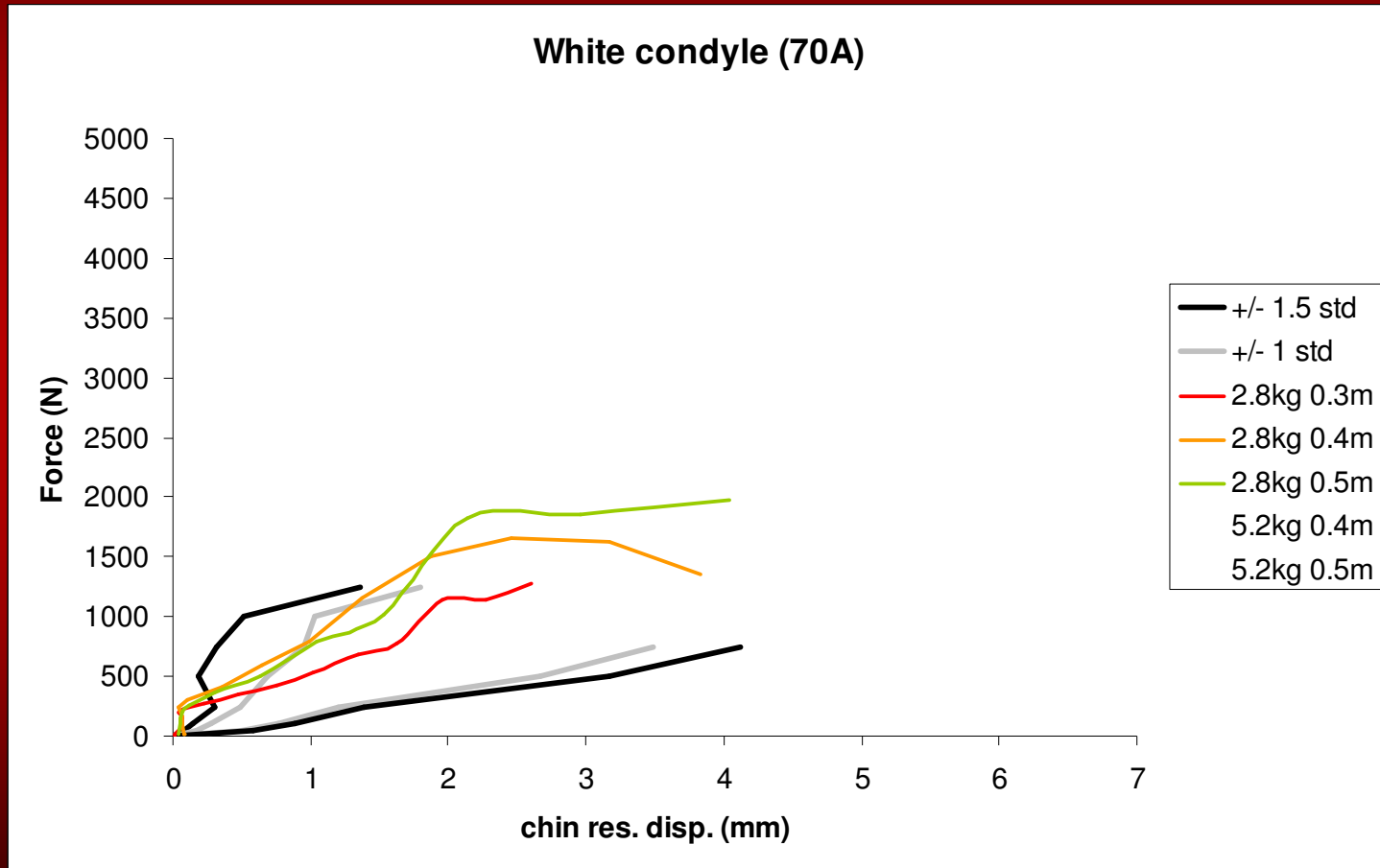
Chin resultant displacement (2.8 kg)



Force data (2.8 kg)

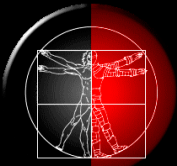
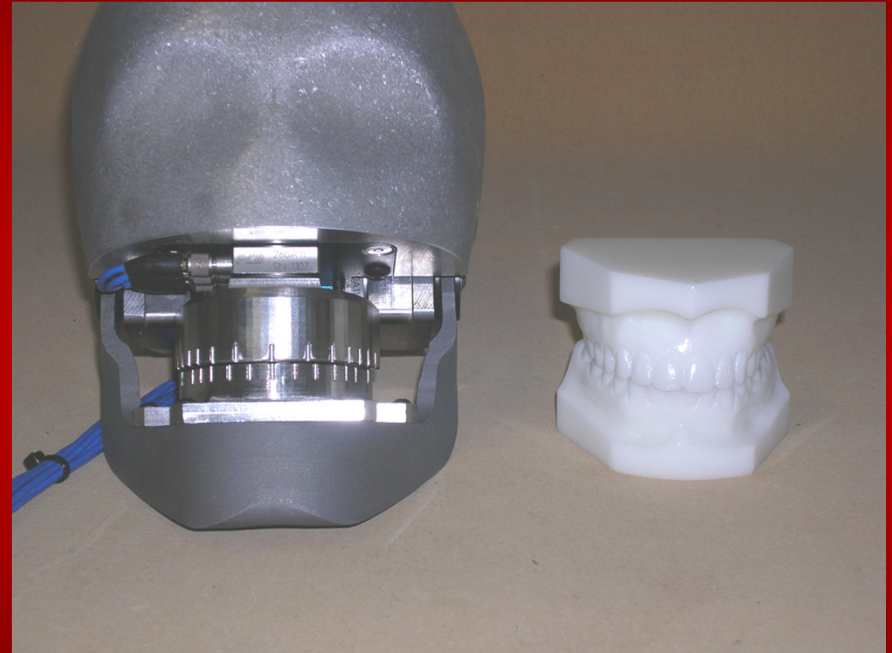


Force-displacement (2.8 kg)



Summary

- ▶ Prototype headform developed
- ▶ Mouthguard compatible
 - *Force reduction*
 - *Head acceleration*
- ▶ Initial validation tests positive
- ▶ WSU cadaver data by end 2006



Continuing work:

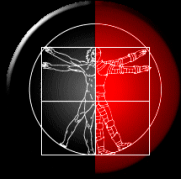
- ▶ Further validation at lower energy
- ▶ Mouthguard testing (late 2006)
- ▶ Football helmet impacts (late 2006)

Future considerations:

- ▶ Role of dentition facets,
- ▶ Update to final WSU criteria



BIOKINETICS



Engineered Solutions for Impact Protection