Development of a Modified Hybrid III ATD for Head Impact Exposure Device Validation

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Introduction/Objective

- Mild traumatic brain injuries (mTBI) are a common issue from contact exposure in all levels of sports [1].
- Researchers have developed specialized head impact exposure (HIE) sensors that track head kinematics [2].
- Measuring kinematics under varying impact conditions can help uncover and explore correlation between impact, head movement, and injury potential.
- HIE systems work through assumed rigid coupling to the skull; this is the major challenge for this technology as without a high degree of coupling the impact data collected may be unrepresentative of actual skull movements [3].
- Sensors used in the field therefore must be validated against reference data sets created through controlled in lab testing to ensure accuracy and precision of the collected data.
- The goal of this effort is to produce a platform, that effectively tests commonly used HIE systems, specifically earpieces and mouthguards, under various degrees of coupling with participant specific geometry.

Background

- The DASHR (Data Acquisition System Head Response) earpiece is a custom fit HIE system containing a triaxial accelerometer and gyroscope that rigidly fit inside a user's bony ear canal.

- Instrumented mouthguards (iMGs) contain accelerometers and gyroscopes that rigidly fit onto a user's upper dentition with help from the closing of the lower jaw.

https://preventbiometrics.com/

- ATD platforms are available to test HIE systems, most notably the MLSH and Modified NOCSAE [4-9].
- Current platforms have some limitations in functionality, specifically for use with earpiece systems.

Methodology

- The Hybrid III (HIII) 50th percentile Male ATD headform was selected to be used for modification due to the material and accessibility.
- Modifications were developed and completed in Autodesk Fusion using the Humanetics FE simulation model and custom part modeling.
- Upper dentition and bony ear canal geometries are participant specific μCT meshes that form into interchangeable components for use in the modified headform.

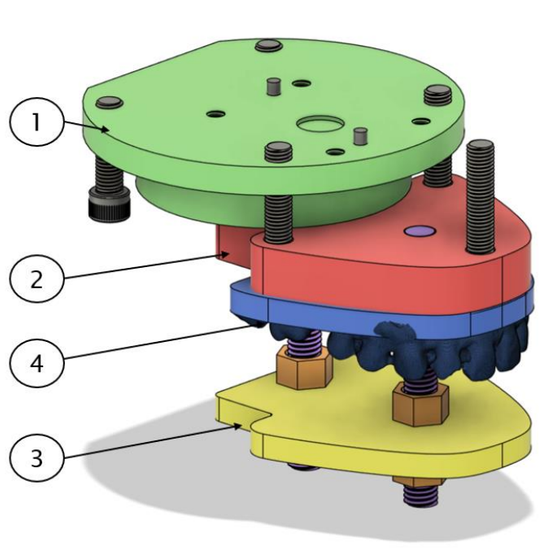
Mandible/Maxilla Module:

1. Headform (LC structural replacement) Insert – Similar to the original HIII LC structural replacement component with a flat bottom face for compatibility with other mandible/maxilla module components.
2. Mandible/Maxilla Upper Insert – Acts as the base for the mandible/maxilla, threads and threaded rods hold other components, connects to the original HIII holes plus an additional hole.
3. Mandible/Maxilla Bottom Clamp – Adjustable vertically, allows different coupling conditions to be explored depending on position, slides over threaded rods and is held by sets of nuts.
4. Upper Dentition – 3D printed participant geometry that connects to the upper insert.

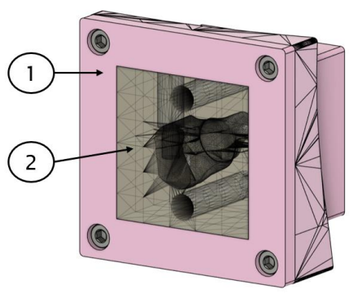
Ear Module:

1. Exterior Housing – Holds the ear geometry, connects to the side of the headform through added milled headform holes.
2. Bony Ear Canal – 3D printed participant geometry, different configurations with TPU layer 'skin' and geometry offsets allow different degrees of coupling to be explored.

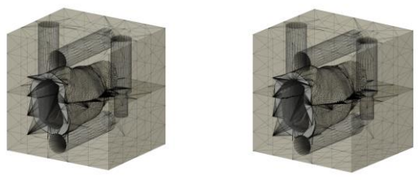
Results



Mandible/Maxilla Module



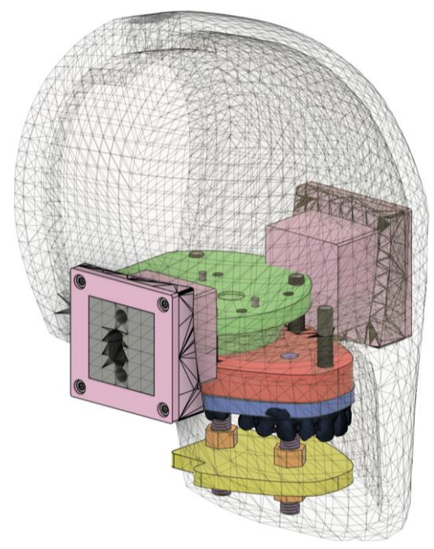
Reverse molded geometry of original bony ear canal



TPU 'skin' options with increasing geometry offsets

Ear Module

Modified Headform



Discussion

- This headform provides a platform for validation of HIE systems and differing degrees of coupling to be explored in earpieces and iMGs through adjustable designs and interchangeable components that consider participant geometry.
- Drop test matrices can be performed with low complexity, and high efficiency.
- Positioning of the dentition and ear canal vary slightly from the 50th percentile male geometry due to space restrictions in the headform and the center of gravity is slightly altered. These limitations are anticipated to be minor due to the usage case of the headform which is to explore variations in coupling between HIE sensors and industry standard 6DOF sensor arrays in the ATD.

Conclusions/Ongoing Work

- Manufacturing of this headform has created a reliable, repeatable, and reusable tool where validation of HIE systems can be explored.
- Varying degrees of coupling can be obtained for two different HIE system types.
- Following its currently ongoing manufacturing, this headform will be the basis for multiple studies examining the effects of coupling on Duke University's earpiece sensor and various iMGs. These will improve confidence and reduce error in using data acquired from wearable systems by providing referential decoupling datasets for implementing screening protocols for any compilation of in-field data.

References/Acknowledgements

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