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

Blake T. Robertson, Mitchell Z. Abrams, Jason F. Luck

[1] Blake T Robertson
Duke University, Department of Biomedical Engineering, Injury Biomechanics Laboratory
RM 1427 Fitzpatrick CIEMAS, 101 Science Drive, Durham, NC 27708
blake.robertson@duke.edu
704-345-5498
Research Completed at: Duke University, Department of Biomedical Engineering
Seeking M.S., Degree Completion: December 2025
Advisor: Jason F. Luck

[2] Mitchell Z Abrams, PhD
Duke University, Department of Biomedical Engineering, Injury Biomechanics Laboratory
RM 1427 Fitzpatrick CIEMAS, 101 Science Drive, Durham, NC 27708
mitchell.abrams@duke.edu
845-596-6009

[3] Jason F Luck, PhD
Duke University, Department of Biomedical Engineering, Injury Biomechanics Laboratory
RM 1427 Fitzpatrick CIEMAS, 101 Science Drive, Durham, NC 27708
jason.luck@duke.edu
919-660-5152

Introduction: Mild traumatic brain injuries are a common occurrence at all levels of sports. Concussion can arise from contact exposure in athletic play and may result in long-term health impacts. To understand the conditions that lead to a concussive event, researchers have developed specialized head impact exposure (HIE) sensors that track head kinematics. Wearable systems like instrumented mouthguards (iMGs) and earpieces, measure kinematics through connections to the skull which are assumed to be rigid. Creating these rigid connections comes with challenges as without proper coupling a sensor system will gather data that is not entirely representative of the actual movements of the skull. Validating these sensors with realistic coupling conditions is therefore important to assessing the accuracy and precision of HIE data collection.

Objective: To modify an industry standard anthropomorphic test device (ATD) headform with interchangeable, biofidelic ear and mandible attachments for use with subject-specific geometry to assess mouthguard and earpiece HIE systems under realistic coupling conditions. This builds on similar modified headform approaches adding increased functionality for system testing[1][2][3][4][5][6].

Methodology: A 50th percentile male Hybrid III ATD headform was modified. A biofidelic mandible attachment was affixed to the bottom of the headform in the anatomical location of the jaw. The mandible attachment is 3D printed and consists of a main base, an interchangeable upper dentition, and an adjustable bottom 'bite plate.' The upper dentition is derived from specific subject geometry. An iMG HIE system can be fitted to the upper dentition and tested at different degrees of coupling and mandible interaction. Different levels of clamping pressure and coupling can be achieved through the height adjustable 'bite plate' design. Additionally, holes were milled out of the main headform in the anatomical location of the ears. Biofidelic ear attachments were affixed to the head using these holes. The ear attachments consist of a main exterior housing and removable ear canals. The canals are 3D printed from subject geometry and are two-part reverse molds of the ears. A block of PLA holds the ear canal geometry with a two-millimeter-thick layer of TPU 'skin.' Multiple versions of the same canal are used in which the inner geometry is scaled in half-millimeter increments to create different degrees of coupling in testing with HIE earpiece systems. Testing results can be compared to the standard headform six-degree-of-freedom sensor array.

Results: Manufacturing of this headform has created a reliable, repeatable, and reusable tool where validation of HIE systems can be explored. Multiple degrees of coupling can be obtained for two different HIE system types. This novel design allows the executing of large test matrices exploring the effects of coupling in multiple head impact scenarios on system accuracy.

Conclusions: Coupling can be explored through this novel modified ATD headform. This headform will be the basis for multiple studies examining the effects of coupling on Duke University's earpiece sensor and various iMGs. Studies like 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.

Insert one figure or table to support your work (optional):

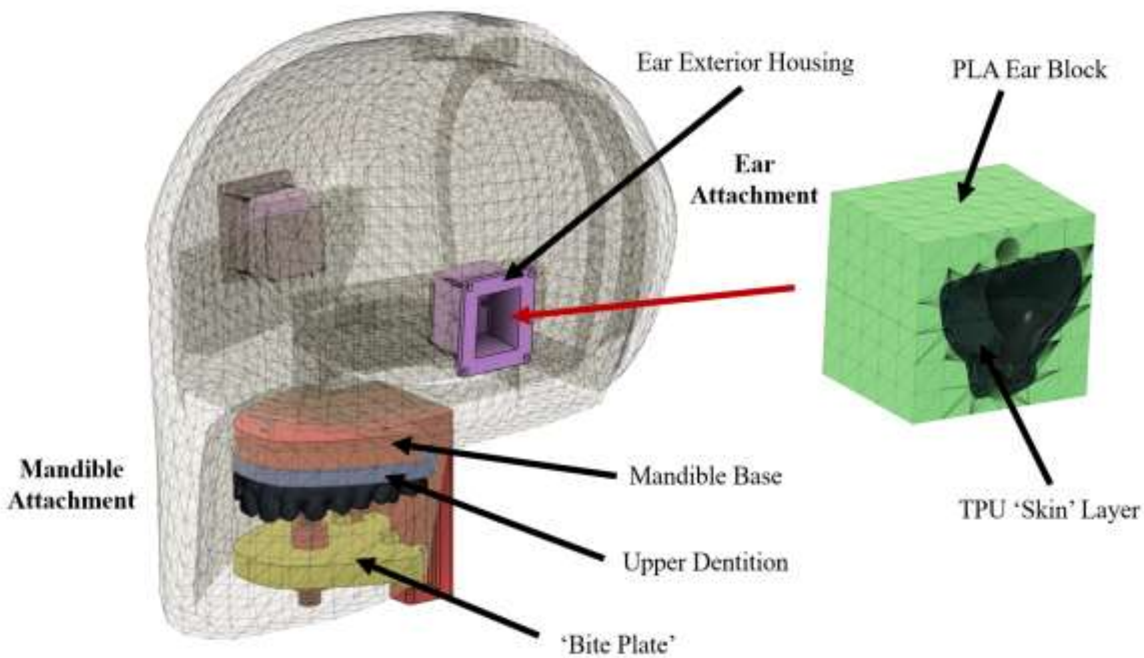

Figure 1. The labeled 3D CAD model of the mandible and ear attachments inside the Hybrid III ATD headform without its outer skin layer.

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