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Additive Manufacturing of Cranial Simulants for Blast Induced Traumatic Brain Injury

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Introduction

The widespread use of improvised explosive devices (IEDs) in warfare has resulted in devastating injuries to United States military personnel, with blast induced traumatic brain injury (TBI) a possible outcome. Blast TBI results in significant damage to intracranial vasculature and tissue interfaces, presumably because of relatively sharp changes in mechanical properties at boundaries between different materials. Nevertheless, understanding of this damage mechanism is largely lacking, limiting early detection and prevention efforts.

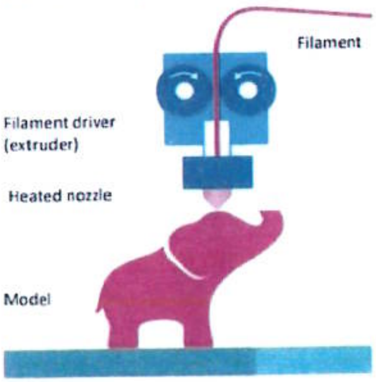
Purpose Statement

The purpose of this study is to produce models of the human head with materials that simulate the mechanical properties of the skull and its contents. In particular, we seek to simulate interfaces between CSF-brain, gray-white, and vasculature-brain.

Fabrication Techniques

The models are fabricated using a combination of manufacturing techniques:

- Fused deposition modeling: casting molds
- Casting: white and gray matter
- Polymerization of injected solution: vasculature



Fused deposition modeling. A plastic filament is fed into a nozzle. The nozzle melts the filament and deposits layers of fused material to form the model. Used to fabricate the casting molds.

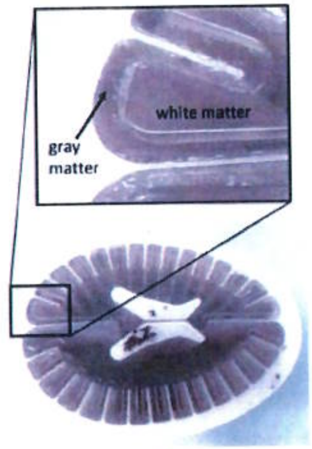
Production Process

Two-Step Casting of Gray/White

Plastic Molds for White Matter Bovine Gelatin

STEP 1: Casting White Matter

Pouring Gelatin in the White Matter Assembly



STEP 2: Casting Gray Matter Around the White Matter

Vasculature

These simulated vessels are formed using the polymerization of aqueous sodium alginate ($C_6H_9NaO_7$) injected via a syringe into aqueous calcium chloride ($CaCl_2$)

Microscope Image of a Hollow Sodium Alginate Structure

Conclusion

Additive manufacturing provides a cost effective fabrication method which is well suited for producing low volume, complex parts using multiple materials. This fabrication technique has the potential to greatly improve the realism of experiments conducted to understand the biomechanics of blast injury. Furthermore, this potential was exploited to produce a highly detailed cranial simulant including multiple materials that closely mimic the mechanical properties of cranial and cerebral tissues at blast wave relevant conditions.

Future Work

Blast tube testing will be conducted on the test objects at Energetic Materials Research and Testing Center (EMRTC), with the implementation of Digital Image Correlation (DIC) and Particle Image Velocimetry (PIV) to characterize the evolution of damage caused by an explosively driven shockwave. Future iterations of the test object will refine the cranial simulant to more closely match the mechanical properties of human tissue and bone, as well as improving the 3D geometry of the molds. These improvements will enable the production of a higher fidelity test object.

Mold and Ballistic Gelatin Sample of Realistic Brain Geometry

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