3D Printing of the Temporal Bone for Surgical Simulation

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Problem

Otolaryngology (ENT) residents and surgeons perform over **16 million procedures** each year in the United States. These procedures **require high fidelity training models** to gain knowledge of the anatomy and properties of the bone for various temporal bone procedures.

Training tools for these surgeries are essential to the advancement of the field, as current training modalities are **expensive**, **difficult to source** and often **do not accurately mimic haptic properties of temporal bone**.

Background

- Temporal bone encompasses the middle and inner portions of the ear.
- It is responsible for important physiological functions (ex. hearing, balance).
- Procedures are high-risk and require specific technical skills due to the complex anatomy of the bone and the surrounding soft tissue.
- Current training models include cadaver bones, which are expensive and difficult to source.
- There is a gap in the market for a surgical simulation platform that is low cost and high efficacy.

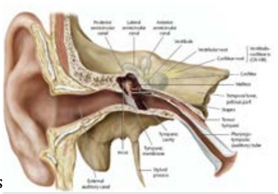

Figure 1: Anatomy of the temporal bone

Objectives

Our model provides a way to scale and **more easily produce** temporal bone models while **addressing the high-cost** of these models for **surgical residents** to **learn Otolaryngology procedures** on accessible, durable models at a high standard of quality for seamless transition from training to real life surgery.

Table 1: Project stakeholder analysis

Stakeholders	Outcomes
Patients	Improved patient outcomes
Surgical residents	Increased quantity of training models
Surgeons	Higher surgeon skills & confidence
Hospitals	Economic relief

Final Prototype

Figure 2: Temporal bone model in right side (left), isometric (middle), and frontal (right) views

Our temporal bone model is 3D printed out of PETG (*Figure 2*) and is generated from a patient-specific CT scan (*Figure 3*).

It contains an internal, open-cell triangular lattice structure (*Figure 4*). Epoxy resin serves as the continuous matrix, filling the open space in the lattice to form our composite material (*Figure 5).*

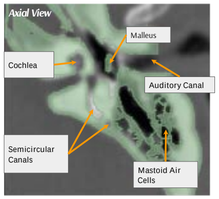

Figure 3: complex anatomical features are preserved

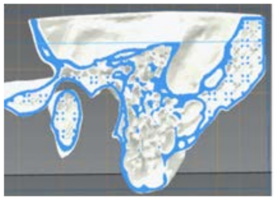

Figure 4: Internal lattice structure generated on FabPilot

Figure 5: Resin is injected into the 3D structure

Our prototype is:

1. **Less expensive** than conventional temporal bone simulation platforms
2. **Accurately resembles the mechanical properties** of temporal bone
3. **Anatomically accurate**
4. Adaptable and can be made **patient specific**

Demonstration and Material Testing

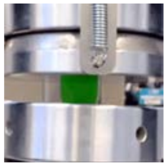

Figure 5: Compression testing of PETG cube sample for yield strength and elastic modulus

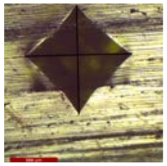

Figure 6: Microhardness indentation of PETG

Figure 7: Drilling through temporal bone model with otologic drill and diamond burr

Table 2: Mechanical comparison of final prototype to cadaver bone

Material	Yield Strength (GPa)	Microhardness (HV)	Compressive Modulus (GPa)
Final Prototype	.0454±.011	14.854±.430	1.24±.066
Temporal Bone	0.042 ± 0.019**7	12.2 - 34.6 HV *6	3.30 - 9.65 *6

Surgical Simulation Results

Table 3: Surgeon Results

Survey Category	Material Score
Haptic Response	3.75
Drill Time/Speed	3
Auditory Response	3
Dust Generation	4.5
Color	2.875
Usefulness for learning drilling technique	4.75
Usefulness for simulating surgery	4
Overall likeness	3.5

Score	Comparison
5	Identical
4	Very Similar
3	Similar
2	Very different
1	Unlike

"It's a great training tool, a lot of this is muscle memory… nice physical and mental exercise for drilling."

Dr. Philip Zapanta, *GW University of Medicine Associate Professor of Surgery, Otolaryngology Residency Program Director*

Pathway to Market

Manufacturing Costs

Considering labor cost, machine upkeep, and raw materials we were able to design a bone that is up to **17x cheaper** than cadaver specimens.

Table 2: Cost breakdown of model

Cost Breakdown	Cost ($)
Material Cost	3.97
Production Cost	37.12
Total Cost	**$41.09**

Reimbursement and Regulatory Pathway

- Since our model is purely to train surgeons and residents, it is unlikely that the cost will be reimbursed as a training platform.
- The model may be classified as a **Class I device** and not be subject to 501(k) clearance or premarket approval.

Patentability

In order to be patentable, our solution must be novel, useful, and nonobvious.

Novel: No other existing patents that use similar technology as ours
Useful: Provides valuable training for surgical residents
Nonobvious: Innovative composite material rather than solid, pure material

Acknowledgements

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