A Novel Temporal Bone Simulation Model Using 3D Printing Techniques

Sarah Mowry, MD1; Hachem Jammal, MD1; Charles Myer, IV, MD2,3; C. Arturo Solares, MD1; Paul Weinberger, MD1
1 Georgia Regents University, Department of Otolaryngology-Head and Neck Surgery, Augusta, Georgia; 2 Division of Pediatric Otolaryngology – Head and Neck Surgery, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio; 3 Department of Otolaryngology – Head and Neck Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio

ABSTRACT

Interest in non-cadaveric representations of the temporal bone for resident education is intense as access to human cadaveric temporal bone preparations has become difficult in many parts of the world.

To this end, a number of groups have published information about temporal bone dissection simulation systems in the last decade.

Described simulation systems involve both virtual reality computer-based systems and physical models which can be physically dissected in a laboratory setting.

The explosion of technology in inexpensive personal desktop 3D printers has resulted in an increased interest in this technology for medical purposes.

These devices are currently available for purchase for relatively little ($1500-$7000), print with inexpensive material, and can be housed in a personal office space.

The goal of this study is to develop a protocol for creation of a 3D temporal bone model on a consumer grade, commercially available desktop printer which successfully recreates temporal bone anatomy including mastoid architecture and demonstrates a similar haptic response to human cadaveric tissue.

METHODS AND MATERIALS

DICOM images from a CT scan of a normal temporal bone were converted to .STL file using OsirX software (Geneva, Switzerland). Secondary processing of the .STL images using Netfabb Basic (Leipzig, Germany) was also performed.

The repaired .STL files were then loaded into the MakerBot 2x (Brooklyn, NY). The temporal bone model was printed using ABS filament with 1mm custom internal supports of HIPS filament at the build platform interface.

Custom print settings were used: 80% infill, 2 layers on the shell and layer height of 0.3mm, 235°C at the extruder and the platform was maintained at 118°C. After printing, the HIPS was dissolved in a D-limonene bath for 48 hours.

The printed model was then subjected to microdissection using a high-speed otologic drill by five experienced neurotologists. Surgeons were asked to evaluate the model on anatomic characteristics and haptic feedback using a Likert scale (Figure 3).

RESULTS

Results of the questionnaire are shown in Table 1.

The MakerBot 2x 3D printer was able to create a temporal bone model using the settings described in the materials and methods (Image 1 and 2).

Each model used approximately 23 grams of ABS and 15 grams of HIPS during printing. The average print time per model was 3.5 hours. Each model cost $1.92 in material costs (based on February 2015 ABS and HIPS pricing).

See a video of this model being microdissected at: https://www.dropbox.com/s/xnVix8zemqwv8ye4/3d%20temporal%20bone.mov?dl=0

DISCUSSION

Synthetic temporal bone models have been shown to have both face and content validity1,2. However the 3D printers used to produce these models costs approximately $60,000 (Zprinter 650)3 and use proprietary powders that are laid down and then fixed with resins which cost >$400 per canister4.

A model which uses varying ratios of thermoset polymers to recreate soft tissue as well as bone has demonstrated face validity but uses a commercial-grade rapid prototyping printer to achieve the different anatomic structures5.

The model described here uses a desktop 3D printer available for purchase on the internet with materials that are inexpensive and readily available.

The major cost of the present model is the 3D printer itself. The retail price of the MakerBot 2x is $2499.

Unlike human cadaveric tissue which may require special processing of waste water and elevated biosafety precautions, plastic models do not and can be drilled anywhere sawdust and irrigation are available.

Thus the need for an expensive formal temporal bone laboratory is not necessary.

CONCLUSIONS

- An inexpensive synthetic temporal bone can be made on a consumer grade 3D printer.
- This synthetic temporal bone demonstrated face validity when dissected by 5 expert surgeons

REFERENCES


INTRODUCTION

Hypothesis: An inexpensive, high fidelity temporal bone model for use in a temporal bone dissection laboratory setting can be made using a commercially available, consumer-grade 3D printer.

Background: Several models for a simulated temporal bone have been described but use commercial-grade printers and materials to produce these models. The goal of this project was to produce a plastic simulated temporal bone on an inexpensive 3-D printer that recreates the visual and haptic experience associated with drilling a human temporal bone.

Methods: Images from a high-resolution CT of a normal temporal bone were converted to stereolithography files via commercially available software, with image conversion and print settings adjusted to achieve optimal print quality. The temporal bone model was printed using Acrylonitrile Butadiene Styrene (ABS) plastic filament on a MakerBot 2x 3D printer. Simulated temporal bones were drilled by 5 neurotologists, assessing the fidelity of the model as compared to a human cadaveric temporal bone. Using a 4-point Likert scale, the simulated bones were assessed for haptic experience and recreation of the temporal bone anatomy.

Results: The created model was felt to be an accurate representation of a human temporal bone. All raters felt strongly this would be a good training model for junior residents or to simulate difficult surgical anatomy. Material costs for each model was $1.92.

Conclusion: A realistic, inexpensive and easily reproducible temporal bone model can be created on a consumer-grade desktop 3D printer.