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3D printed temporal bone as a tool for otologic surgery simulation☆

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ABSTRACT

Purpose: In this face validity study, we discuss the fabrication and utility of an affordable, computed tomography (CT)–based, anatomy-accurate, 3-dimensional (3D) printed temporal bone models for junior otolaryngology resident training.
Materials and methods: After IRB exemption, patient CT scans were anonymized and downloaded as Digital Imaging and Communications in Medicine (DICOM) files to prepare for conversion. These files were converted to stereolithography format for 3D printing. Important soft tissue structures were identified and labeled to be printed in a separate color than bone. Models were printed using a desktop 3D printer (Ultimaker 3 Extended, Ultimaker BV, Netherlands) and polylactic acid (PLA) filament. 10 junior residents with no previous drilling experience participated in the study. Each resident was asked to drill a simple mastoidectomy on both a cadaveric and 3D printed temporal bone. Following their experience, they were asked to complete a Likert questionnaire.
Results: The final result was an anatomically accurate (XYZ accuracy = 12.5, 12.5, 5 μm) 3D model of a temporal bone that was deemed to be appropriate in tactile feedback using the surgical drill. The total cost of the material required to fabricate the model was approximately $1.50. Participants found the 3D models overall to be similar to cadaveric temporal bones, particularly in overall value and safety.
Conclusions: 3D printed temporal bone models can be used as an affordable and inexhaustible alternative, or supplement, to traditional cadaveric surgical simulation.

1. Introduction

Surgical simulation is a critical component of medical training, the earliest iteration being that of cadaveric dissections. The use of surgical simulators has been shown to provide real value and allow for the acquisition of skill sets that are transferable to the operating room [1]. In addition to improving the technical skill of a surgeon, simulation ultimately protects patients by reducing medical errors [2,3]. As technology has improved, there has been an emergence of more realistic and complex training models. More recently, surgical simulation is evolving via virtual reality and three-dimensional (3D) printing to provide increasingly more accurate training experiences [4]. Many believe that these simulations will soon be advanced enough for use in standardized testing and certification, particularly for otolaryngologic surgery [5].

The temporal bone is among the most complex and difficult anatomy that otolaryngologists encounter and the challenges of safely operating within this area demand a robust and realistic resident training laboratory. The gold standard for surgical stimulation of temporal bone drilling is the use of cadaveric bone [6]. Unfortunately, cadaveric temporal bone is expensive ($300 to 500 per pair) and often in short supply [7]. There has been a continued effort by otolaryngologists to create an accurate training environment that does not rely on cadaveric specimens. Trials of hybrid virtual reality and force-feedback haptic systems show satisfactory surgical training, though residents still prefer cadaveric dissection [8]. Studies of 3D printed temporal bone models demonstrate significant likeness to cadaveric bone in drilling and dissection, though the printer ($250,000) and materials used ($400) are expensive [9]. Indeed, the cost of adoption is a common issue shared by many surgical simulators. Haptic-based virtual reality systems cost between $4000–5000 and only allow one trainee per station. While 3D printing technology has recently become more affordable, the cost of wide-scale adoption needed for the high-volume simulation required in residency training programs is still often

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