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Evaluating the Use of Cleft Lip and Palate 3D-Printed Models as a Teaching Aid

Ahmad B. AlAli, MBBS, MSc,[*,†,1] *Michelle F. Griffin, MBChB, MSc, MRes, MRCS, PhD,*[*,†,1] *Wenceslao M. Calonge,*[*,†] *and Peter E. Butler, MD, FRCSI, FRCS, FRCS (Plast)*[*,†,‡]

[*]UCL Division of Surgery & Interventional Science, Centre for Nanotechnology & Regenerative Medicine, University College London, London, United Kingdom; [†]Charles Wolfson Center for Reconstructive Surgery, Royal Free Hospital, London, United Kingdom; and [‡]Department of Plastic and Reconstructive Surgery, Royal Free London NHS Foundation Trust Hospital, London, United Kingdom

OBJECTIVE: Visualization tools are essential for effective medical education, to aid students understanding of complex anatomical systems. Three dimensional (3D) printed models are showing a wide-reaching potential in the field of medical education, to aid the interpretation of 2D imaging. This study investigates the use of 3D-printed models in educational seminars on cleft lip and palate, by comparing integrated "hands-on" student seminars, with 2D presentation seminar methods.

SETTING: Cleft lip and palate models were manufactured using 3D-printing technology at the medical school.

PARTICIPANTS: Sixty-seven students from two medical schools participated in the study.

DESIGN: The students were randomly allocated to 2 groups. Knowledge was compared between the groups using a multiple-choice question test before and after the teaching intervention. Group 1 was the control group with a PowerPoint presentation-based educational seminar and group 2 was the test group, with the same PowerPoint presentation, but with the addition of a physical demonstration using 3D-printed models of unilateral and bilateral cleft lips and palate.

RESULTS: The level of knowledge gained was established using a preseminar and postseminar assessment, in 2 different institutions, where the addition of the 3D-printed model resulted in a significant improvement in the mean percentage of knowledge gained (44.65% test group; 32.16%; control group; $p = 0.038$). Student experience was assessed using a postseminar survey, where students felt the 3D-printed model significantly improved the learning experience ($p = 0.005$) and their visualization ($p = 0.001$).

CONCLUSIONS: This study highlights the benefits of the use of 3D-printed models as visualization tools in medical education and the potential of 3D-printing technology to become a standard and effective tool in the interpretation of 2D imaging. (J Surg Ed ■:■■■-■■■. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEYWORDS: 3D printing, education, visualization, cleft lip and palate, teaching aid, additive manufacturing

COMPETENCIES: Medical Knowledge, Patient Care, Practice Based Learning and Improvement, Interpersonal Skills and Communication

INTRODUCTION

Three-dimensional (3D) printing is a rapidly developing technology, where a physical structure is created to a specific 3D pattern at high resolutions, using relatively simple computer aided design software and a 3D printer, creating a physical 3D object from digital imaging files.[1,2] The development of this progressive technology was made possible with the introduction of helical scanning techniques in the 1990s, which revolutionized computed tomography imaging, allowing highly precise image segmentation and rendering methods that led to the development of digital image editing techniques such as the creation of polygonal meshes for the manipulation of anatomical structures, which forms the basis of 3D-printing technology.[2]

Correspondence: Inquiries to Michelle F. Griffin, MBChB, MSc, MRes, MRCS, UCL Division of Surgery & Interventional Science, University College London, London, United Kingdom; e-mail: 12michellegriffin@gmail.com

[1] Joint first authors.

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The field of 3D printing is showing significant promise and importance in a range of medical fields and despite some current limitations (such as cost, the complexity of processes, and availability of 3D-printing technology), it shows significant potential to become an easily accessible technology, particularly with the development of desktop 3D printers, which are becoming increasingly commonplace in hospitals and institutions.[3] There is much current research evaluating the uses, advantages and limitations of many 3D printers in practice, but the benefits are clear, including but not limited to surgical planning; patient education; the creation of highly specific prosthesis and implant structures; and medical education.[4-10]

Various studies have found that the use of 3D-printed models in both medical and surgical education resulted in better performance and learning experience in students, compared to those who used 2D methods, such as 3D virtual computed tomography-rendered images, digital models or textbooks (Fig. 1).

A study by Preece et al., used 3D-printed models to aid understanding and interpretation of magnetic resonance imaging (MRI) anatomy, compared to 2D methods.[7] The effectiveness of the different teaching methods was assessed by the student's ability to identify MRI images and the study found that assessment scores were significantly higher in students using the 3D-printed model (86.39%), a 23.78% increase over use of a textbook and 22.7% increase over digital 3D-printed models ($p < 0.001$).

Another study comparing the use of 3D models to digital 3D imaging and static 2D imaging as anatomy teaching aids, involved a 10-minute seminar followed by an assessment. The use of the 3D model resulted in a significant improvement in performance (3D model 67%; 2D model 40%; and 3D digital 41%).[8] It is of note that in both these studies there was no observable difference found between the effectiveness of textbooks and 2D digital representation of 3D-imaging, supporting the argument that little additional benefit is gained from viewing a 3D image from a 2D perspective, such as on a computer screen. An interesting finding of the Khot et al.,[8] study was that computer-based learning resources appear to have significant disadvantages compared to traditional specimens in learning nominal anatomy.

A significant problem with data comparison in many of these studies is that the parameters used to gage effectiveness of the use of 3D models vary greatly, can be subjective and often contain endpoints that are not repeated in other studies. This means that some interpretation is required as to whether the parameters being assessed are directly comparable. An example of this is the study by Costello et al.,[9] where the use of 3D-printed models as a teaching tool in educational seminars, was assessed for its effectiveness using preseminar and postseminar knowledge assessment questionnaires. The study found that the use of 3D-printed models increased knowledge acquisition scores significantly, although comparisons to other studies are made difficult as the level of understanding was graded by a knowledge acquisition score, on a scale of 1-10, rather than measure such as the overall percentage increase in knowledge.

Although the potential benefits of using 3D-technology are clear,[10] the aim of the present study was assessment of its effectiveness in the medical education environment, compared to conventional education techniques. We have created and previously reported a 3D-printed cleft lip and palate model using imaging data.[11] However, in this study we investigated the relative understanding and degree of knowledge gained by students, using the 3D-printed model integrated seminar on cleft lip and palate, as compared to conventional 2D teaching methods. For both the educational method groups this study compares standard endpoints of improvement in test score, degree of knowledge gained and student experience and satisfaction assessment.

MATERIAL AND METHODS

Model acquisition

This study used DICOM files provided with permission from Prof. Yoshiaki Hosaka (Plastic Surgery Department, Showa Univeristy, Tokyo, Japan) as a source for modeling 3D-printed models identical to defects presented in cleft lip and palate cases where full imaging data were available. The DICOM files were then further processed. Files were converted from DICOM files to the .OBJ format, using the software MeshLab, to allow files to be imported into the various programs required. DICOM data were combined with other parts, such as the complete skull, using a separate model imported into the 3D modeling program along with the DICOM. The mesh integrity was confirmed and corrected using the software applications ZBrush and MeshLab.

Before the DICOM data were combined with other parts, all parts were aligned and all redundancy removed. The final model size was determined and the scale of the 2 models corrected accordingly for alignment of *X-Z* coordinates. Individual vertices of the file were then combined in ZBrush, where both DICOM and full skull images were duplicated and retopologized. Lower-resolution versions (100,000 polygons) were created, combined and exported as .OBJ files into Autodesk Maya, for the lower-level vertex work and to combine vertices, where both meshes were combined into one and all vertices were manually combined along the seam. The combined file was then exported as an .OBJ file.

Final sculpting of the .OBJ file was then conducted. Using ZBrush, holes were closed so mesh was made solid and skull was refined along the seam using the smooth brush. The high-resolution details were projected onto the