PEC Innovation 1 (2022) 100077

Contents lists available at ScienceDirect

PEC Innovation

journal homepage: www.elsevier.com/locate/pecinn

Utility of 3-dimensionally printed models for parent education in pediatric plagiocephaly

Pouya Entezami *, Morgan P. Spurgas, Michael W. O'Brien, Lisa C. Newman, Matthew A. Adamo

Department of Neurosurgery, Albany Medical Center, Albany, NY, United States of America

ARTICLE INFO

Keywords:
3D
Craniosynostosis
Education
Parent education
Patient satisfaction
Plagiocephaly

ABSTRACT

Objectives: Demonstrate the benefits of using 3D printed skull models when counseling families regarding disorders of the cranial vault (namely plagiocephaly and craniosynostosis), as traditional imaging review and discussion is often insufficient.

Methods: 3D printed skull models of a patient with plagiocephaly were used during clinic appointments to aid in the counseling of parents. Surveys were distributed following the appointment to evaluate the utility of these models during the discussion.

Results: Fifty surveys were distributed (with a 98% response rate). 3D models were both empirically and anecdotally helpful for parents in understanding their child's diagnosis.

Conclusion: Advances in 3D printing technology and software have made producing models more accessible. Incorporating physical, disorder-specific models into our discussions has led to improvements in our ability to communicate with our patients and their families.

Innovation: Disorders of the cranial can be challenging to describe to the parents and guardians of affected children; using 3D printed models is a useful adjunct in patient-centered discussions. The subject response to the use of these emerging technologies in this setting suggests a major role for 3D models in patient education and counseling for cranial vault disorders.

1. Introduction

Rapid advancements in three-dimensional (3D) printing equipment and software have improved the accessibility of physical reconstructed models. The translation of these tools into the arena of healthcare has been sporadic and primarily focused on medical education. Only a handful studies highlight the effectiveness of 3D printed models in patient education.

The past decade has seen an increased emphasis on patient-centered decision making in Neurosurgery [1]. The added element of a surrogate decision maker – in the case of a parent or guardian consenting for surgery or treatment on behalf of their child – further increases the importance of ensuring adequate understanding of the underlying pathology. Recent studies have shown that patients desire to become more familiar with unfamiliar situations. Augmented reality tools have been shown to be a powerful augment to traditional counseling methods [2]..

Neurological disorders can place a psychological burden on parents and caretakers as well as the patients themselves [3]. Disorders of the cranial vault – namely plagiocephaly and craniosynostosis – are challenging to understand even for those with some medical knowledge. Our center routinely uses plastic reconstructed models to help counsel parents and/or guardians of their child's diagnosis.

2. Methods

2.1. Printing models

Neuronavigation protocol, 1.0 mm slice computer tomography (CT) of the cranium was performed per routine practice to evaluate cranial sutures in pediatric patients with concern for craniosynostosis and positional plagiocephaly. Raw Digital Imaging and Communication in Medicine (DICOM) data of the bone window was obtained from the hospital Picture Archiving and Communications System (PACS). DICOM data set was then sorted, deidentified converting to Nearly Raw Raster Data (NRRD) format using Slicer.org software. The anonymized NRRD file was then converted to Stereolithography (STL) file format using Democratiz3D® software. Smoothing and extraneous material captured during the CT scanning such as head holders, cervical vertebrae, and artifacts were removed using Autodesk® Fusion360. The edited file is then once again saved to STL file format and transferred to Prusaslicer 2.1.0. Using the slicer software, specific print criteria were selected prior to printing.

Based on previous anatomical prints we have found 0.15 mm thickness with 15% infill provides an accurate, strong, high quality final print. Given the complexity of skull models and overhangs, the print is sliced utilizing

* Corresponding author at: Albany Medical Center, 47 New Scotland Ave MC-10, Albany, NY 12208, , United States of America.
E-mail address: entezap@amc.edu (P. Entezami).

http://dx.doi.org/10.1016/j.pecinn.2022.100077
Received 10 February 2022; Received in revised form 11 August 2022; Accepted 18 August 2022

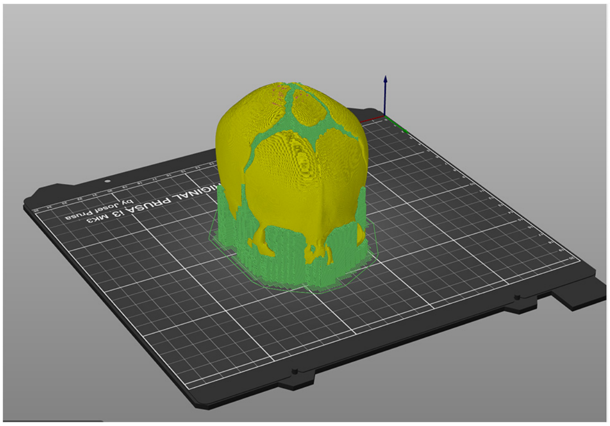

Fig. 1. Rendered 3D model sliced with supports prior to printing. These supports are removed after the model is printed.

supports to minimize sagging especially around the orbits of the model (Fig. 1). The final 3D model was then sliced and converted to Geometric code (G-code) using PrusaSlicer 2.1.0 and printed on a PRUSA i3 MK3 (Prusa Research, Prague, Czech Republic) utilizing polyactic acid 1.75 mm white filament with extruder and bed temperature of 210 and 60 degrees Celsius respectively. Final processing was completed which requires removing support material from the orbits and neuroforamina utilizing needle nose pliers.

2.2. Surveys

Institutional review board approval was obtained prior to collecting surveys. Participants included the parents or guardians of fifty pediatric patient presenting to the neurosurgical clinic for their initial visit with referral diagnosis of plagiocephaly. Informed consent was obtained for their participation in the study.

A board-certified pediatric neurosurgeon acted as the primary facilitator for the patient interaction. Patients underwent the normal clinic interview including obtaining a detailed history, physical examination, and patient/parent counseling regarding the diagnosis; at our institution imaging review with careful explanation is part of the discussion as well. Imaging for plagiocephaly as provided by referring physicians can include 2-Dimensional scans (computed tomography [CT], magnetic resonance imaging [MRI], or plain radiographs) as well as 3D CT reconstructions if available.

Subsequently, a disorder-specific physical 3D model of a child with plagiocephaly was then introduced and used as an adjunct for counseling parents and guardians regarding their child's diagnosis. Following the clinic visit, participants were asked to complete a simple 4-question quantitative questionnaire regarding their experience. The questions were answered using an ordinal ranking scale, from excellent (5), very good (4), good (3), fair (2), and poor (1). Survey questions included:

1) How would you rate your understanding of your child's diagnosis prior to today?
2) How would you rate your understanding of your child's diagnosis after you were counseled and had a chance to review the imaging?
3) How would you rate your understanding of your child's diagnosis after you saw the 3 dimensionally (3D) printed model?
4) How would you rate the usefulness of the 3D model in understanding your child's diagnosis during your clinic visit?

3. Results

Fifty consecutive patients were surveyed and asked to fill out a simple 4-query questionnaire at the end of their visit (Table 1). One patient opted out of the survey resulting in a 98% response rate. The average age of the child at presentation was 5.3 months.

Table 1
Survey responses.

QUESTION	AVERAGE SCORE
How would you rate your understanding of your child's diagnosis prior to today?	3.4
How would you rate your understanding of your child's diagnosis after you were counseled and had a chance to review the imaging?	4.4
How would you rate your understanding of your child's diagnosis after you saw the 3 dimensionally (3D) printed model?	4.9
How would you rate the usefulness of the 3D model in understanding your child's diagnosis during your clinic visit?	4.8

For question one, designed to recognize the parent/guardian's baseline understanding of their child's diagnosis, the most common score was 3 (average 3.4), implying that most felt they had a “good” understanding of the diagnosis prior to the appointment.

For the next two questions, the average score was 4.4 after traditional counseling with imaging review, and 4.9 after 3D models were used. This demonstrated an expected increase in parent/guardian understanding of the pathology with counseling, but also further improvement when the models were used. A majority of those surveyed felt the models were useful (average score 4.8).

4. Discussion

In comparison to traditional counseling – which in our practice includes an in-depth discussion of the diagnosis, imaging review, and management options – the 3D models helped improve the understanding of patients and guardians. Anecdotally, those surveyed often remarked at the utility of the models and the ease of understanding the diagnosis when they could hold the model and see it in person.

With the increasing recognition of the importance of shared decision-making and parental understanding of a child's disease process comes the need for improved education tools and methods [1,4]. Improved communication can help reduce conflict and confusion, particularly in a high-risk field such as pediatric neurosurgery [4-6]. This collaborative approach between providers and parents can help in providing optimal care [7]..

Several studies have demonstrated the value of 3D printed models in improving patient comprehension in various disease processes [8-11]. A randomized trial comparing personalized 3D printed models to native and reconstructed 3D images for patients with lumbar degenerative disease helped improve patient understanding as well as their satisfaction scores [12].

3D models may also play a role in pre-operative consultation [13]. Visual tools can help improve recall, as Sezer et al. demonstrated. In their study, patients preparing to undergo glioma surgery had improved recall of their pre-operative consultation when 3D models were used [14]. Patient-specific models have been shown to be effective in glioma surgery, improving patient understanding of their disease process as well as the surgical risks. Similar positive benefits have been shown when counseling patients for aneurysm clipping and endoscopic sinus surgery [15,16].

Some authors have noted that patients may experience an emotional response as a negative effect of confronting a physical model of their disease process [17]. Subjectively, this was not the case when discussing plagiocephaly with parents or guardians in our cohort. However, timing a survey to follow immediately after the appointment could result in a biased response in parents or guardians with a strong emotional response to discussing their child's diagnosis.

In our practice we utilize disorder-specific models (e.g., the parents of children with fusion of the sagittal suture were shown a scaphocephalic skull, and so forth), though other authors have suggested that generic models may be as effective for patient education. Khural et al.

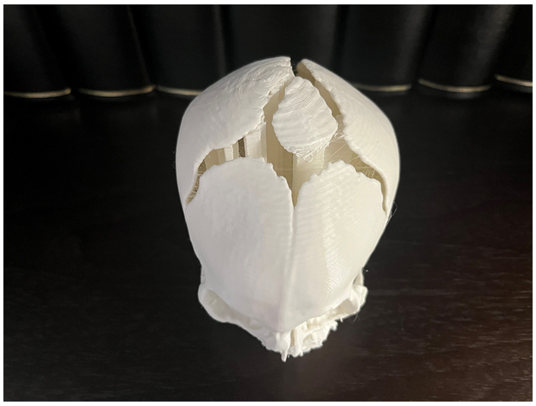

Fig. 2. A 3D model printed from the CT scans of a child with trigonocephaly. Metopic suture synostosis is demonstrated.

demonstrated that generic aortic aneurysm models were equally effective, though this would require validation for craniosynostosis [9]. Nevertheless, producing two (one with plagiocephaly and another with any type of craniosynostosis) 3D models may be sufficient with regards to educating patients for centers without access to a 3D printer. While this study only surveyed parents of children presenting with plagiocephaly to reduce variability, we have anecdotally had similar results when counseling those with a diagnosis of craniosynostosis (Fig. 2).

Improvements in both 3D printer technology and software in recent years have also increased the utility of 3D models in medical education. Models can serve as a tool for students and surgical trainees/residents alike, both with respect to anatomical learning as well as simulation training [18-23]. In addition, there is great utility in demonstrating rare or difficult operations. Reconstructed physical models have been shown to improve surgical performance, particularly in novice surgeons [24]. As the cost of the elements required to produce these tools decreases, the availability of 3D models for both patient care and educational uses will continue to increase [12].

5. Innovation

We hope this paper has helped those who would like to print such models understand the methodology and benefit of using physical models to counsel parents and guardians regarding pediatric disorders of the cranial vault. The response of our subjects to physical models suggests a strong role for using these new technologies in the education and counseling of parents and guardians of children with cranial vault disorders.

6. Conclusions

Printed 3D models can help when educating parents and guardians on disorders of the cranial vault, such as plagiocephaly or craniosynostosis. Improved access to 3D printing technology and resources has made these models more readily available and less expensive, and these models may help improve patient-provider communicating, especially for these complex diagnoses.

Financial support

None.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Robin AM, Kalkanis SN, Rock J, Lee I, Rosenblum ML. Through the patient's eyes: an emphasis on patient-centered values in operative decision making in the management of malignant glioma. J Neurooncol. 2014;119(3):473–9.
[2] der Linde-van den Bor M, Frans-Rensen SA, Slond F, Liesdek OCD, de Heer LM, Suyker WJL, et al. Patients' voices in the development of pre-surgical patient education using virtual reality: A qualitative study. PEC Innovat. 2021;1:100015.
[3] Nevin SM, Wakefield CE, Dadich A, LeMarne F, Macintosh R, Beavis E, et al. Hearing parents' voices: A priority-setting workshop to inform a suite of psychological resources for parents of children with rare genetic epilepsies. PEC Innovat. 2021;1:100014.
[4] Corell A, Guo A, Vecchio TG, Ozanne A, Jakola AS. Shared decision-making in neurosurgery: a scoping review. Acta Neurochir. 2021;163(9):2371–82.
[5] Shinkunas LA, Klipowicz CJ, Carlisle EM. Shared decision making in surgery: a scoping review of patient and surgeon preferences. BMC Med Inform Decis Mak. 2020;20(1):190.
[6] Boss EF, Mehta N, Nagarajan N, Links A, Benke JR, Berger Z, et al. Shared decision making and choice for elective surgical care: A systematic review. Otolaryngol Head Neck Surg. 2016;154(3):405–20.
[7] Say RE, Thomson R. The importance of patient preferences in treatment decisions–challenges for doctors. BMJ. 2003;327(7414):542–5.
[8] Wake N, Rosenkrantz AB, Huang R, Park KU, Wysock JS, Taneja SS, et al. Patient-specific 3D printed and augmented reality kidney and prostate cancer models: impact on patient education. 3D Print Med. 2019;5(1):4.
[9] Khural M, Gullipalli R, Dubrowski A. Evaluating the use of a generic three-dimensionally (3D) printed abdominal aortic aneurysm model as an adjunct patient education tool. Cureus. 2020;12(6):e8533.
[10] Biglino G, Koniordou D, Gasparini M, Capelli C, Leaver LK, Khambadkone S, et al. Piloting the use of patient-specific cardiac models as a novel tool to facilitate communication during cinical consultations. Pediatr Cardiol. 2017;38(4):813–8.
[11] Silberstein JL, Maddox MM, Dorsey P, Feibus A, Thomas R, Lee BR. Physical models of renal malignancies using standard cross-sectional imaging and 3-dimensional printers: a pilot study. Urology. 2014;84(2):268–72.
[12] Zhuang YD, Zhou MC, Liu SC, Wu JF, Wang R, Chen CM. Effectiveness of personalized 3D printed models for patient education in degenerative lumbar disease. Patient Educ Couns. 2019;102(10):1875–81.
[13] Bernhard JC, Isotani S, Matsugasumi T, Duddalwar V, Hung AJ, Suer E, et al. Personalized 3D printed model of kidney and tumor anatomy: a useful tool for patient education. World J Urol. 2016;34(3):337–45.
[14] Sezer S, Piai V, Kessels RPC, Ter Laan M. Information recall in pre-operative consultation for glioma surgery using actual size three-dimensional models. J Clin Med. 2020.;9(11).
[15] Kim PS, Choi CH, Han IH, Lee JH, Choi HJ, Lee JI. Obtaining informed consent using patient specific 3D printing cerebral aneurysm model. J Korean Neurosurg Soc. 2019;62(4):398–404.
[16] Sander IM, Liepert TT, Doney EL, Leevy WM, Liepert DR. Patient education for endoscopic sinus surgery: Preliminary experience using 3D-printed clinical imaging data. J Funct Biomater. 2017.;8(2).
[17] van de Belt TH, Nijmeijer H, Grim D, Engelen L, Vreeken R, van Gelder M, et al. Patient-specific actual-size three-dimensional printed models for patient education in glioma treatment: first experiences. World Neurosurg. 2018;117:e99-105.
[18] Bartellas M. Three-dimensional printing and medical education: A narrative review of the literature. Univ Ottawa J Med. 2016;6(1):38–43.
[19] Tack P, Victor J, Gemmel P, Annemans L. 3D-printing techniques in a medical setting: a systematic literature review. Biomed Eng Online. 2016;15(1):115.
[20] Bohl MA, Mauria R, Zhou JJ, Mooney MA, DiDomenico JD, McBryan S, et al. The barrow biomimetic spine: Face, content, and construct validity of a 3D-printed spine model for freehand and minimally invasive pedicle screw insertion. Global Spine J. 2019;9(6):635–41.
[21] Bohl MA, McBryan S, Pais D, Chang SW, Turner JD, Nakaji P, et al. The living spine model: A biomimetic surgical training and education tool. Oper Neurosurg (Hagerstown). 2020;19(1):98–106.
[22] Bohl MA, Zhou JJ, Mooney MA, Repp GJ, Cavallo C, Nakaji P, et al. The Barrow Biomimetic Spine: effect of a 3-dimensional-printed spinal osteotomy model on performance of spinal osteotomies by medical students and interns. J Spine Surg. 2019;5(1):58–65.
[23] Kimura T, Morita A, Nishimura K, Aiyama H, Itoh H, Fukaya S, et al. Simulation of and training for cerebral aneurysm clipping with 3-dimensional models. Neurosurgery. 2009;65(4):719–25. [discussion 725-6].
[24] Chen Y, Bian L, Zhou H, Wu D, Xu J, Gu C, et al. Usefulness of three-dimensional printing of superior mesenteric vessels in right hemicolon cancer surgery. Sci Rep. 2020;10(1):11660.