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3D-Printed models as an improvement in medical professionals' education

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Abstract

Increasing usage of 3D-Printed models draws attention as a cheap alternative to traditional tools used in anatomy education and post-graduate training. Models can be self-prepared using existing DICOM files and printed on consumer-level printers using widely available materials. Prepared models benefit from high approval rate from students, multiplicity of printable structures and high detail accuracy. They can be used in wide range of medical training, for e.g., otolaryngology, neurosurgery, oncology, neuroradiology. Positive outcomes include greater eligibility for resident training, surgical planning and

education, when compared to market available anatomical models. Additive manufacturing is expected to increase its presence in medical education.

Keywords: 3d printing, teaching anatomy, additive manufacturing, medical education

Introduction

Anatomy as an experience-based subject requires constant usage of best available tools to be taught properly. [1] However, widespread availability of cheap 3D-Printers allows now in-house and fast creation of life-like 3D models. [2] Self-made models can be used in cardiovascular diseases, tumors, patient specific structures, which all can influence teaching capabilities. [3] Usage of printed models may potentially be the most effective tool to be used by students. [4] Additive manufacturing usage in medical schools is expected to rise, as it can be even tenfold cheaper than conventional alternatives. [5] This can be also helpful at post-university stage, for e.g., during preoperative planning and preparing residents for new procedures. [6]

Methods

The search of articles was conducted on 4th April 2023 Articles searched for were focused on the topic of weight changes among incarcerated people. Databases used in the search included: PubMed and Google Scholar. Search query included articles not older than 5 years. Inclusion criteria: keywords: “3D printing teaching anatomy”; “3D Printing Medical Education”; “3D Printing Anatomy Models”

Exclusion criteria: Articles not compatible with the topic, Articles older than 5 years; Articles written in language other than English; Duplicate Articles; Incomplete Articles and Preprints

Results

Searching with inclusion criteria provided 1167 identified articles. Screening 947 original articles discarded 895 articles due to exclusion criteria. 52 articles were sought for retrieval and provided 31 reports assessed for eligibility.

Screening provided 22 articles included in the review.

Preparing Models

A good way to prepare a model from scratch is to use a CT scanner to get DICOM files of the patient, preferably with slim slice thickness. Prepared DICOM files can be imported into 3DSlicer program and there converted to printable file. [7] Prepared files can be post-processed in Autodesk Meshmixer®, version 3.1 (Autodesk Inc.©, California, United States) [2], and then used in 3D Printing Slicer of choice, for e.g., Prusa Slicer 2.5.2 (Prusa Research, Prague, Czech Republic). Prepared G-Code File can be fed to printer, so it can extrude a model in material such as ABS (Acrylonitrile butadiene styrene) or PLA (Poly (Lactic Acid)) [7] [2]

Training Usages

3D Printing technology has potential for creating models that provide similar value to dissections in surgical procedures. [7] They can be also used as decent education tool for patients, residents, students and surgeons. [8] Interestingly, educational models tend to be more effective in junior years of residency. [9] Models are also effective at improving Flexible Nasopharyngoscopy and are highly valued as a teaching method by trainees. Agreement was made that the model should be standardized in radiation oncology training. [10] Complex anatomy can be difficult to comprehend for interns. However, models also here provide a viable option to be popularized in hospitals for e.g., during Henle trunk education. [11] It's worth noting that in case of a short time being available it may be a viable option to transfer 3D models to VR headsets, before a physical one can be printed. It allows physicians to quickly analyze data in emergency endovascular procedures. [12] 3D Printing also has an impactful rise in surgical assistance. It can provide guidance, planning, and training on a broad spectrum of tissues. Combination of 3D-Printing both soft and hard tissue may be beneficial in neurosurgical training. [6] Rapid prototyped heart models provide accurate anatomical structures. Even 93% of clinicians evaluate them as good or above. It provides a decent opportunity for medical individuals to practice on human heart models. [13] Conventional market-sold anatomic models lack required details to be suitable for resident education. However, printed models are allowing otolaryngologists and neuroradiologists to be educated with high-detail, low-cost tools with accurate anatomy. [14] Models are on a rising trend of approval in otolaryngology education. They provide positive surgical and educational outcomes. [15] 3D Printed models are also valuable in ventricular system simulation and can be successfully developed to improve teaching quality. They also make a

more positive impact than 3D images. [16] Usage of 3D Printed teeth models can be also viable in improving preclinical dentistry training quality. [17]

Teaching Anatomy

3D printing is an easily accessible tool in undergraduate anatomy education. It provides an interesting way to learn structures difficult to make specimens of. [5] Physical models are advantageous when compared to 2D images by allowing more perception and engagement for students. Benefits of 3D Models include reducing psychological distress for anatomy students, due to odorlessness and dryness when compared to traditional materials. [18] 3D-Printed heart models objectively improve students' learning performance. Students strongly agree that they are more useful than images. Knowledge among students with access to heart models improved higher than among students without such access. [19] Printed models stand out by achieving accuracy, high test scores and student satisfaction. [20]

Discussion

The principle of this review is to show advantages and opportunities that 3D-printing gives to medical education. Models obtained with that method can be used through the whole process - starting with studying anatomy as a student and ending with learning new medical procedures and even planning complex surgeries. [3], [4] Studies show that 3D models are more effective in anatomy education than traditional methods of learning. [4], [18] Among physicians 3D models can be used in preoperative planning, analyzing tumors and training before major surgeries what at the end allows to achieve better therapeutic results. [3], [21] Moreover, 3D-printing is being used not only in learning and preparing for the surgeries, but also it is used in a therapeutic process as a source of precise models made from specific materials that can be used as a replacement for natural tissues of the patient. [22]

It is worth mentioning that this technology is still developing - models are becoming more and more accurate and the used materials are getting better. [8] Both 3D-printers and standard models from common materials are cheap and accessible, which should make this technology widely accessible. [3], [5] 3D-models also have their limitations. As they can be an accurate anatomical model, they can't show the movement and dynamic changes affecting the organ. [3] Moreover, it is desirable to have a model that, thanks to used materials, mimics the tissues making it more realistic. [3], [5] On the other hand, those limitations may be potential

development paths for this technology, thus making it more usable and truer to source material.

Conclusions

As we report it is important to take 3D-printing into consideration as a tool that allows us to better understand medical issues at every level of medical education. Learning anatomy with usage of 3D-models showed benefits in comparison to standard 2D-models. [5] It is also useful among doctors who can visualize, plan and prepare for surgeries with usage of such models. [3] Even though that method still has its limitations, it may also be a chance for future development.

References

[1] W. Gbolahan Balogun, "Using electronic tools and resources to meet the challenges ofanatomy education in sub-Saharan Africa," *Anat. Sci. Educ.*, vol. 12, no. 1, pp. 97–104, Jan. 2019.

[2] A. de S. Lima, M. Machado, R. de C. R. Pereira, and Y. K. de Carvalho, "Printing 3D models of canine jaw fractures for teachingundergraduate veterinary medicine," *Acta Cir. Bras.*, vol. 34, no. 9, p. e201900906, Dec. 2019.

[3] Z. Sun, Y. H. Wong, and C. H. Yeong, "Patient-specific 3D-printed low-cost models in medical educationand clinical practice," *Micromachines (Basel)*, vol. 14, no. 2, Feb. 2023.

[4] D. Chytas *et al.*, "Three-dimensional printing in anatomy teaching: current evidence," *Surg. Radiol. Anat.*, vol. 42, no. 7, pp. 835–841, Jul. 2020.

[5] J. Yuen, "What is the role of 3D printing in undergraduate anatomyeducation? A scoping review of current literature andrecommendations," *Med. Sci. Educ.*, vol. 30, no. 3, pp. 1321–1329, Sep. 2020.

[6] A. Ganguli *et al.*, "3D printing for preoperative planning and surgical training: areview," *Biomed. Microdevices*, vol. 20, no. 3, p. 65, Aug. 2018.

[7] M. Bartikian, A. Ferreira, A. Gonçalves-Ferreira, and L. L. Neto, "3D printing anatomical models of head bones," *Surg. Radiol. Anat.*, vol. 41, no. 10, pp. 1205–1209, Oct. 2019.

[8] E. Maglara *et al.*, "Three-dimensional (3D) printing in orthopedics education," *J. Long Term Eff. Med. Implant.*, vol. 30, no. 4, pp. 255–258, 2020.

[9] R. Vatankhah *et al.*, "3D printed models for teaching orbital anatomy, anomalies

andfractures," *J. Ophthalmic Vis. Res.*, vol. 16, no. 4, pp. 611–619, Oct. 2021.

[10] C. D. Goodman *et al.*, "Evaluation of a 3-dimensional-printed head simulation techniquefor teaching flexible nasopharyngoscopy to radiation oncologyresidents," *Int. J. Radiat. Oncol. Biol. Phys.*, vol. 109, no. 2, pp. 317–323, Feb. 2021.

[11] Y. Chen *et al.*, "3D printing technology improves medical interns' understandingof anatomy of gastrocolic trunk," *J. Surg. Educ.*, vol. 77, no. 5, pp. 1279–1284, Sep. 2020.

[12] J. Stana, M. Grab, R. Kargl, and N. Tsilimparis, "3D printing in the planning and teaching of endovascularprocedures," *Radiol.*, vol. 62, no. Suppl 1, pp. 28–33, Dec. 2022.

[13] S. Krishnasamy, R. A. R. Mokhtar, R. Singh, S. Sivallingam, and V. Aziz Yang Faridah Abduland Mathaneswaran, "3D rapid prototyping heart model validation for teaching andtraining - A pilot project in a teaching institution," *Braz. J. Cardiovasc. Surg.*, vol. 36, no. 5, pp. 707–716, Oct. 2021.

[14] C. M. Low, G. Choby, M. Viozzi, and J. M. Morris, "Construction of three-dimensional printed anatomic models forfrontal sinus education," *Neuroradiol. J.*, vol. 33, no. 1, pp. 80–84, Feb. 2020.

[15] G. Leung, A. T. Pickett, A. Bartellas Michaeland Milin, M. Bromwich, R. Shorr, and L. Caulley, "Systematic review and meta-analysis of 3D-printing inotolaryngology education," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 155, no. 111083, p. 111083, Apr. 2022.

[16] X. Yi, C. Ding, H. Xu, T. Huang, D. Kang, and D. Wang, "Three-dimensional printed models in anatomy education of theventricular system: A randomized controlled study," *World Neurosurg.*, vol. 125, pp. e891–e901, May 2019.

[17] P. Kustra, K. Dobroś, and J. Zarzecka, "Making use of three-dimensional models of teeth, manufactured bystereolithographic technology, in practical teaching ofendodontics," *Eur. J. Dent. Educ.*, vol. 25, no. 2, pp. 299–304, May 2021.

[18] A. Asghar, S. Naaz, A. Patra, K. S. Ravi, and L. Khanal, "Effectiveness of 3D-printed models prepared from radiologicaldata for anatomy education: A meta-analysis and trial sequentialanalysis of 22 randomized, controlled, crossover trials," *J. Educ. Heal. Promot.*, vol. 11, no. 1, p. 353, Oct. 2022.

[19] C. Karsenty *et al.*, "The usefulness of 3D printed heart models for medical studenteducation in congenital heart disease," *BMC Med. Educ.*, vol. 21, no. 1, p. 480, Sep. 2021.

[20] Z. Ye *et al.*, "The role of 3D printed models in the teaching of humananatomy: a

systematic review and meta-analysis," *BMC Med. Educ.*, vol. 20, no. 1, p. 335, Sep. 2020.

[21] Y. Mao, Y. Liu, Y. Ma, P. Jin, L. Li, and J. Yang, "Mitral Valve-in-Valve Implant of a Balloon-Expandable Valve Guided by 3-Dimensional Printing," *Front. Cardiovasc. Med.*, vol. 9, p. 1337, May 2022, doi: 10.3389/FCVM.2022.894160/BIBTEX.

[22] Y. Feng *et al.*, "Application of 3D Printing Technology in Bone Tissue Engineering: A Review," *Curr. Drug Deliv.*, vol. 18, no. 7, pp. 847–861, Nov. 2021, doi: 10.2174/1567201817999201113100322.