

Letter to the Editor

Three-dimensional printing in medical education: transforming learning and practice!

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Extract

Three-dimensional (3D) printing is revolutionizing medical education, particularly in surgical training, by transforming digital images into tangible models. These models, derived from patient radiological data, allow for enhanced anatomical understanding and hands-on learning. Studies have shown that 3D-printed models significantly improve medical students' comprehension of complex anatomical structures and foster interest in specialized fields such as cardiology. Additionally, 3D printing offers cost-effective solutions for creating both normal and pathological models, which is particularly beneficial in resource-limited settings. While challenges remain, including material limitations and ethical considerations, 3D printing holds tremendous potential in advancing medical education globally.

Keywords

3D printing; Anatomical models; Medical education; Simulation training; Technology

Dear Editor,

Three-dimensional (3D) printing involves the creation of physical objects through geometric representation, utilizing various materials such as polylactic acid, acrylonitrile butadiene styrene, photopolymer resins, titanium, stainless steel, hydroxyapatite, bioglass, and hydrogels such as alginate and gelatin [1,2]. With recent technological advances, 3D printing has become increasingly important in medicine, especially in surgery, as it allows digital renderings to be materialized as physical objects via a printer [3]. As a result, low-cost 3D printers are becoming more accessible. For example, McMenamin et al. highlighted the cost-effectiveness of 3D printing, with upper limb models costing between US\$300 and US\$350, achieving approximately 97.5% cost savings compared with plastinated models (US\$14,000) and approximately 80.6% savings compared with plastic "SOMSO" models (US\$1,800) [4].

3D printing holds potential for creating organ models for surgical practice and drug testing. Anatomical models are extensively utilized in teaching medical students with greater precision and detail [5]. In addition to educational settings, 3D printing has the potential to transform global healthcare, particularly in low- and middle-income countries (LMICs), where access to traditional medical training tools and implants is limited.

The introduction of 3D printing technology aims to enhance students' anatomical understanding by providing precise and customized reproductions. These models, derived from patients' actual radiological imaging, are solid tangible objects that allow for free manipulation by the user. By providing precise 3D representations of proportions, orientations, and configurations, such models enable a deeper understanding of complex anatomical arrangements, even if the models cannot be dismantled. For example, a

randomized controlled trial assessed the understanding of congenital heart defects among fifth-year medical students via 3D-printed heart models [6]. The students who used 3D-printed models scored significantly higher on postlecture assessments (16.3 ± 2.6) than did those who used traditional 2D images (14.8 ± 2.8) ($p < 0.001$). Moreover, the 3D model group reported better self-assessed understanding (4.2 ± 0.5) than did the control group (3.8 ± 0.4), highlighting the effectiveness of 3D models in enhancing knowledge [6].

Building on these findings, it is noteworthy to mention a study that integrated 3D printing technology with case-based learning (CBL) and problem-based learning (PBL) to educate clinical medical students about respiratory diseases. The results were similarly promising: students who engaged in 3D printing demonstrated better performance than those taught via traditional methods did, showing improved clinical thinking, increased confidence, better self-study skills, stronger anatomical knowledge, enhanced problem-solving abilities, and greater satisfaction with the teaching method [7].

3D printing's ability to produce on-demand models has revolutionized how training institutes acquire educational tools. Traditionally, the majority of available models depict normal anatomy, whereas pathological models are rarely available. However, by using Digital Imaging and Communications in Medicine (DICOM) files, it is now possible to transform real cases into physical 3D models, enabling educators to create models of rare pathologies and thereby significantly enhancing the educational experience [8]. Educators determine which pathologies to model on the basis of their educational relevance, complexity, and frequency in clinical practice, prioritizing conditions that require a deeper spatial understanding or are challenging to comprehend through traditional 2D images. This capability has opened new possibilities for interdisciplinary collaboration between fields such as bioengineering, materials science, and medicine, further advancing the integration of cutting-edge technology in medical practice [9].

Despite its advantages, 3D printing technology has several limitations. For example, it demands experience in troubleshooting software and fixing equipment. Moreover, extended printing times can result in time-consuming failures, and many types of materials are still unsuitable for 3D printing [10]. Another challenge is the tactile limitation of 3D models compared with real cadavers. Compared with those who learn on plastic models, students who work on real cadavers tend to develop enhanced skills and gain more practical knowledge of anatomy [11]. Additionally, as 3D printing becomes more common in medical education, ethical considerations regarding the accuracy and safety of printed models and implants should be addressed to ensure that the technology is used responsibly and effectively.

The potential of 3D printing in medical education is immense, yet its full capabilities remain to be fully realized. Continued research and investment are crucial to unlocking the broader applications of this technology in medical training and practice. Future studies may focus on improving tactile realism to improve mimicking human tissues, automating the printing process for increased efficiency, and reducing production costs to make the technology more accessible. By addressing its current limitations and exploring new possibilities, particularly in global health contexts, we can ensure that 3D printing reaches its full potential in shaping the future of medical education.

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