

3D Printing: Print the Future of Ophthalmology

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The three-dimensional (3D) printer is a new technology that creates physical objects from digital files. Recent technological advances in 3D printing have resulted in increased use of this technology in the medical field, where it is beginning to revolutionize medical and surgical possibilities. It is already providing medicine with powerful tools that facilitate education, surgical planning, and organ transplantation research. A good understanding of this technology will be beneficial to ophthalmologists. The potential applications of 3D printing in ophthalmology, both current and future, are explored in this article.

Keywords: 3D printing, ophthalmology, viewpoint

In 2013, for the first time, doctors used a three-dimensional (3D) printer to create a life-saving artificial airway for a baby boy born with a birth defect. His airway was prone to collapse, putting him at constant risk of suffocation, until doctors asked the United States Food and Drug Administration (FDA) for permission to print him a new one.¹

The 3D printer is a new technology that creates physical objects from digital files. Three-dimensional printing, also known as additive manufacturing, was invented in the 1980s but has seen rapid advancements in recent years. Since the start of the 21st century, the sales of 3D printing machines have shown marked growth. Today, 3D printing is widely used, much like printing on 2D surfaces such as paper in everyday experience. It is now possible to print anything: from guns to clothing to car parts to designer jewelry.

This technology has also emerged in the medical field, where it is beginning to revolutionize medical and surgical possibilities. Numerous recently published studies have investigated 3D printing and cell culture in terms of fabrication of blood vessels, vascular networks, bandages, bones, ears, exoskeletons, windpipes, and dental prosthetics (including a jaw bone).²⁻⁶ In the future, this technology is expected to produce corneas and entirely new organs to treat specified diseases. The continuing development of inexpensive and easy-to-use 3D printers increases the likelihood that this technology will soon have major uses in medicine, including ophthalmology. Therefore, a good understanding of this technology will be of unquestionable benefit to ophthalmologists. The aim of this article is to explore the potential applications of 3D printing in ophthalmology, both current and future.

3D PRINTING FOR EYEWEAR AND MEDICAL DEVICES

Three-dimensional printing has advanced to the point where companies are printing consumer grade eyewear with on-demand custom fit and styling. The on-demand customization market for glasses has been made possible by rapid prototyping. Three-dimensional printing simplifies the printing of

medical devices in plastic or metal form,⁷ which is beneficial for ophthalmologists who need many gadgets in their medical activities. In the future, printing of artificial lenses, glaucoma valves, and other medical implants with on-demand patient fit may be possible. The ophthalmic industries should expect to be substantial players in future developments in 3D printing technology.

FOR EDUCATION AND CLINICAL PRACTICE

Three-dimensional models are currently being used in medical schools to introduce surgical techniques to trainees prior to their exposure to live patients.⁸ The use of these models for surgical training simulation allows the trainees to practice surgical procedures in a safe environment and repeat them until they have mastered them. Theoretically, this shortens the learning curve while standardizing the teaching and assessment of these trainees. A recent study⁹ found that students who used 3D models performed better and had a better learning experience when compared with students who used digital models or textbooks, which suggested that the use of 3D models enhances the understanding of anatomical structures and their relationships. Therefore, as 3D printing technology advances, models of this nature may become available to supplement the training of ophthalmologists in a simulated operating theater environment, thereby improving the training experience.

FOR SURGICAL PLANNING

Ophthalmologists encounter complicated anatomic structures of the eye and orbit. For orbital surgery, the intricate and sometimes obscure structural relationships between orbital structures, muscles, vessels, and nerves can be difficult to appreciate fully based solely on radiographic 2D images. The small surgical access field for some ophthalmic cases also means that any error in navigating this complicated anatomy

can have potentially devastating consequences. The creation of anatomically tailored models using 3D printing technology would therefore be very useful for practice and teaching purposes, as these would allow a full appreciation of the anatomic relationships between the lesions and the complicated surrounding structures. The technological advances in 3D printing allow the physical prototyping of 3D models, thereby creating an accurate representation of the actual patient's anatomy.¹⁰ This is an invaluable aid in surgical planning in human medicine and will also provide a better learning experience for the surgeons involved.

FOR PRINTING OF LIVE CELLS, TISSUES, AND ORGANS

Three-dimensional bioprinting, the printing of live cells, tissues, and even organs for implantation, is an active and ongoing field of research. As of 2012, this technology has been studied in academia and by biotechnology firms (e.g., Organovo Co., San Diego, CA, USA) for possible use in tissue engineering applications, where organs and body parts are built using inkjet techniques. In this process, layers of living cells are deposited onto a gel medium or sugar matrix and slowly built up to form 3D structures.¹¹ The use of 3D bioprinting has resulted in the successful printing of blood vessels and vascular networks,³ bones,⁴ and ears,⁵ and so on. In 2014, researchers successfully implanted a 3D-printed skull component into a patient, with no adverse effects. This new technology opens up the opportunity for new implants to be custom-tailored to the patient, for many different applications. The use of 3D bioprinting in ophthalmology is currently limited, but the potential is clear for the generation of ocular tissues (e.g., conjunctiva, sclera, and corneas) using 3D-bioprinting technology in the future.

In summary, 3D printing has the potential to grow into an enormously beneficial technology. It is already providing medicine with powerful tools that facilitate education, surgical planning, and organ transplantation research. At the present time, the use of 3D printing in ophthalmology has not had much impact, but an understanding of this new technology will be beneficial to ophthalmologists at present and in the future.

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