Perspective

Three-Dimensional Printing in Medicine

Promise and Challenge

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SUMMARY

Three-dimensional (3D) printing is a producing technique by which objects are created by depositing materials such as powders, plastic, liquids, metal, ceramics or even living cells in layers to provide a 3D object. Medical applications for 3D printing are increasing quickly and are expected to revolutionize health care. The current medical applications of 3D printing can be categorized into a number of categories: creating implants, tissue and organ fabrication; prosthetics, and pharmaceutical research concerning drug discovery and anatomical models. The usage of 3D printing in medicine industry will offer several benefits, such as: the personalization and customization of medical product, drugs, and equipment; cost-effectiveness; and enhanced productivity. But, it should be cautioned that despite recent important and exciting medical advances of 3D printing, notable scientific and regulatory challenges stay and the most transformative applications for this technology, like organ printing, can take time to evolve.■

KEYWORDS Three-dimensional printing; Organ; Transplantation; Medicine; Technology

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Medical applications for 3D printing are increasing quickly and are expected to revolutionize health care (1). Medical uses for 3D printing, either actual or potential, are organized into many broad classes, including: tissue and organ fabrication; creation of custom-built prosthetics, implants, and anatomical models; and pharmaceutical analysis concerning drug dosage forms, delivery, and discovery (2). The usage of 3D printing in drugs will offer several benefits, such as: the personalization and customization of medical product, drugs, and equipment; cost-effectiveness; and enhanced productivity. but, it should be cautioned that despite recent important and exciting medical advances involving 3D printing, notable regulatory and scientific challenges stay and the most transformative applications for this technology can take time to evolve.

WHAT IS 3D PRINTING?

Three-dimensional (3D) printing is a producing technique by which objects are created by depositing materials such as powders, plastic, liquids, metal, ceramics or even living cells in layers to provide a 3D object. This method is also known as additive producing (AM), rapid prototyping (RP), or solid free-form technology (SFF) (3). Some 3D printers are just like usual inkjet printers; but, the end product differs as a 3D object is made. 3D printing is predicted to revolutionize different fields of life especially medicine.

There are around two dozens 3D printing techniques, which use differing printer technology, paces, resolutions, and several materials. These technologies can manufacture a 3D object in a shape defined in a computer-aided design (CAD). The 3D printer builds the foundation for the object by follows the instructions given in the CAD file. The printer moves the print head along the Cartesian plane as directed by CAD (4). The printer then keeps on following the guidelines, moving the print head along the z-axis to manufacture the article vertically, layer by layer (4). It is vital to note that two-dimensional (2D) radiographic images, including, x-rays, magnetic resonance imaging (MRI), or computerized tomography (CT) outputs, can be converted into 3D files, permitting the creation of complex medical structures.

OVERVIEW OF CURRENT APPLICATIONS

Consumer Uses

3D printing technology is quickly becoming simple and cheap enough to be utilized by consumers. The accessibility of downloadable computer software from the Internet repositories of 3D printing styles has proliferated, mostly because of the increasing applications and reduced cost (5). It is currently possible to print anything, from guns, clothing, and automobile elements to designer jewelry. Thousands of premade styles for 3D items are accessible for downloading, several of them without charge

Commercial Uses

Three-dimensional printing has been used by the production business for many years, primarily to provide product prototypes. Many manufacturers use massive and rapid 3D printers known as “rapid prototyping machines” to create molds and models. A large number of still files are accessible for industrial purposes. Several of the printed objects are similar to the manufactured things.

BENEFITS OF 3D PRINTING IN MEDICAL APPLICATIONS

Increased Cost Efficiency

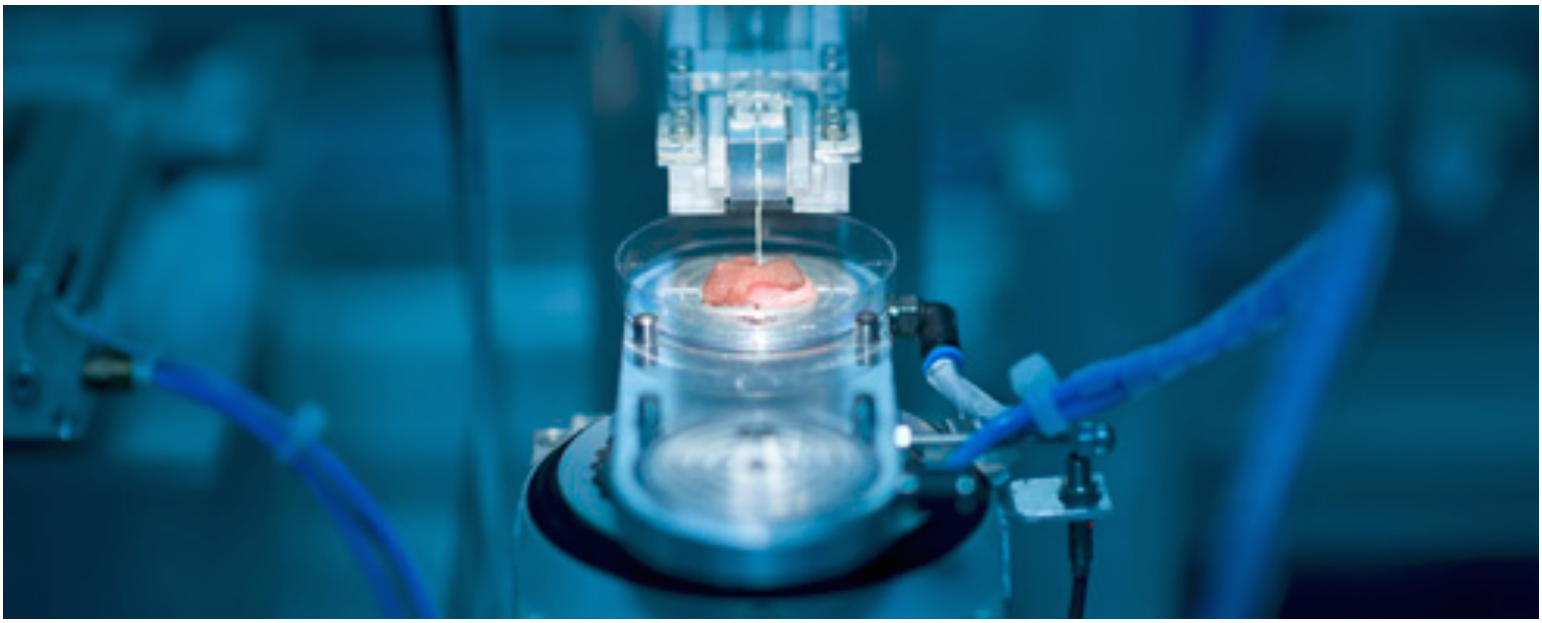
Another vital benefit offered by 3D printing is the ability to provide items cheaply. Traditional producing ways are cost-effective for large-scale production; but the cost of 3D printing is becoming more competitive for small-scale production of implants or prosthetics used for dental, spinal, or craniofacial disorder. The cost to custom-print a 3D object is lowest, with the first item as costly as last. This is particularly advantageous for firms that have low production volumes or that manufacture components or product that are extremely complicated or need frequent modifications. For instance, a pharmaceutical pill weighing ten mg can be custom-fabricated on demand as a one mg pill. Some medication can also be written in dosage forms, making them easier to deliver to patients.

Customization and Personalization

The greatest advantage that 3D printers offer in medical applications is the freedom to make customized medical product and instrumentation (6). For instance, the utilization of 3D printing to customize prosthetics and implants can offer great value for both patients and physicians. In addition, 3D printing can manufacture made-to-order jigs and fixtures to be used in operation rooms. Custom-made implants, fixtures, and surgical tools will have a positive impact in terms of the time needed for surgery, patient recovery time, and therefore the success of the surgery or implant. It is anticipated that 3D printing technologies can eventually enable drug dosage forms, unleash profiles, and dispensing to be custom-made for every patient.

Enhanced Productivity

Quick in 3D printing means that a product can be produced within hours. This makes 3D printing technology much quicker than traditional ways of creating items like medicine and implants, that need milling, forging, and an



extended delivery time. In addition to speed, different qualities, like the resolution, accuracy, dependability, and repeatability of 3D printing technologies, also are rising.

Democratization and Collaboration

Democratization of the planning is another useful feature offered by 3D printing. An increasing amount of material is becoming obtainable to be used in 3D printing. This enables more individuals, including those in medical fields, to use a 3D printer and their imaginations to style and manufacture novel product for personal or business use.

MEDICAL APPLICATIONS FOR 3D PRINTING

Since the early 2000s, 3D printing has been applied in medicine. It was first used to manufacture custom prosthetics and dental implants (3). Since then, the medical applications for 3D printing have evolved significantly. Reviews that are published recently describe the use of 3D printing to produce exoskeletons, windpipes, a jaw bone, bones, ears, blood vessels, vascular networks, tissues, eyeglasses, cell cultures, stem cells and organs.

The current medical applications of 3D printing can be categorized into a number of categories: creating implants, tissue and organ fabrication; prosthetics, and pharmaceutical research concerning drug discovery and anatomical models. Details of these medical uses are given below.

Bioprinting Tissues and Organs

Tissue or organ failure attributable to aging, diseases, accidents, and birth defects is a crucial medical problem (7). Current treatments for organ failure depends totally on organs donated for transplant from living or deceased donors. However, there's a chronic shortage of human organs obtainable for transplant. An additional downside is that organ transplantation involves the usually difficult task of finding a donor who could be a tissue match (8). This problem can be solved by 3D bioprinting.

Although still in its infancy, 3D bio printing offers extra benefits as compared to ancient regenerative method (which primarily provides scaffold support alone), such as: extremely precise cell placement and high digital management of speed, resolution, and diameter of printed cells.

Customized Implants and Prostheses

Implants and prostheses can be printed in any conceivable geometry through the interpretation of x-ray, MRI, or CT scans into digital stl 3D print files. In this manner, 3D printing has proven successful in the health care sector to create both standard and complicated custom-made prosthetic limbs and surgical implants, typically within twenty-four hours (9). This method has been used to fabricate spinal, dental, and hip implants. Previously, before clinical use of implants, they had to be valid, that is an extremely long process.

Anatomical Models for Surgical Preparation

The variances and complexities of the anatomy in individuals make the utilization of 3D-printed models ideal for surgical training. Having a tangible 3D printed model of a patient's anatomy accessible for a doctor to review or use to simulate surgery is preferred to relying exclusively on MRI or CT scans, that aren't as instructive since they are viewed in 2 dimensions on a flat screen. The utilization of 3D-printed models for surgical coaching is also desirable to coaching on cadavers, who have cost and availability issues. Cadavers typically lack the suitable pathology, so they might be suitable for anatomy lessons but not for surgery.

Custom Printed Drug Delivery Devices and Dosage Forms

3D printing techniques have already been used in fabrications and pharmaceutical researches, and they promise to be transformative.5 Benefits of 3D printing include precise management of droplet size and dose, high reliability, and

therefore the ability to provide dosage forms with advanced drug-release profiles.

Complex drug producing processes might even be standardized through use of 3D printing to make them less complicated and more viable. 3D printing technology can be important for the development of personalized drugs, too.

Challenges in Building 3D Vascularized Organs

Bioprinting has been successful in producing organs, but the printed organs are simple and miniature. Mostly the printed organs are alymphatic, thin, or hollow, avascular, aneural, get their nourishment by the diffusion from host vasculature. But when thickness of these printed tissues reaches 200 micrometers, problem of oxygen diffusion between host and transplanted cell arise. As a result, the printed organs that is complex, and need precise multicellular structure that has integrated vascular network, which has not been accomplished yet.

Most organs needed for transplantation are often complex, like the liver, kidney and heart. Cells of these large structures are bound to fail if proper vascularization is not provided to them. Therefore, efforts should be made to print functional vascularization into fabricated organs.

CONCLUSIONS

3D printing has become a helpful and potentially transformative tool in different fields, including medication. The uses of 3D printing have increased with the passage and so have its performance and resolution. The medical benefits of 3D printing are exciting and significant, but some of the applications, like organ printing, will need time to evolve.■

ARTICLE INFORMATION

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Study concept and design: Both of authors.
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