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Review Article

Emerging Technologies In 3D Printing in Healthcare: A Review

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ABSTRACT

3D printing advanced by the 1980s. The term "three dimension-al (3D) printing" refers to a variety of manufacturing techniques and technologies that use digital data to create a tangible, genuine model. In the medical industry, 3D printing was once an ambitious goal that has now been put into reality. But time, progress, technology, and money made it a reality. The speedy creation of medical implants, the ability to help pharmaceutical and medical corporations create more specialized pharmaceuticals, and the manner that physicians and surgeons plan surgeries have all been made possible by 3D printing technology. In the current precision medicine practice and for customized therapies, targeted patient-specific 3D-printed models are becoming more and more helpful technology instruments. Ad-ditional-ly, it's likely that 3Dprinted implantable organs will become accessible, which will shorten waiting lists and save more lives in the future. Addi-tive manufacturing for healthcare is still very much a work in progress, but it is already applied in many different ways in medical field that, already reeling under immense pressure with regards to optimal performance and reduced costs, will stand to gain unprecedented benefits from this good-as-gold technology. By thoroughly examining the uses of 3D printing in the medical profession, this review aims to show the technology's benefits, limitations, and overall power.

INTRODUCTION

3D Printing

A broad range of manufacturing processes that construct product components layer by layer are included under the umbrella term "3D printing." Three-dimensional printing comes in a variety of forms, such as stereolithography (SLA), selective laser sintering (SLS), fused deposition modeling (FDM), digital light processing (DLP), multijet fusion (MJF), polyjet, and direct metal laser sintering (DMLS), Melting of electron beams (EBM) Understanding the advantages and

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disadvantages of each 3D printing process and connecting those characteristics to the necessary product development requirements is necessary to choose the best one for the application.

3D Printing for Rapid Prototyping and Beyond

It's safe to assume that prototyping is the most common usage of 3D printing. Because it can produce a single part fast, product developers may validate and share ideas in an economical way. Choosing the best 3D printing method for your prototype will depend on its intended use. Simple physical models and parts for functional testing are only two examples of the kinds of prototypes that additive manufacturing can be used for. There are situations in which 3D printing is a practical production method, even though it is almost always associated with rapid prototyping. Usually, complex geometries and low volumes are involved in these applications.

Stereolithography (SLA)

The first method of industrial 3D printing was stereolithography (SLA). SLA printers are excellent at creating products with precise tolerances, smooth surface finishes, and a high degree of detail. In addition to being aesthetically pleasing, SLA parts' high-quality surface finishes can help with the part's functionality, such as verifying an assembly's fit. The medical field makes extensive use of it, and common applications include microfluidics and anatomical modeling. For SLA parts, we employ 3D Systems' Vipers, ProJets, and iPros 3D printers.

Selective Laser Sintering (SLS)

Powdered nylon is melted together to create solid plastic via selective laser sintering (SLS). Because SLS parts are constructed from genuine thermoplastic, they are robust, appropriate for functional testing, and able to accommodate snap-fits and living hinges. Parts feature rougher surface finishes but are stronger than SL. Because SLS doesn't require support structures, it may be used to nest numerous pieces into a single build, which makes it appropriate for larger part quantities than other 3D printing techniques. In order to develop designs that will eventually be injection-molded, many SLS pieces are utilized. We use 3D Systems' sPro140 printers for our SLS printing.

PolyJet

Another plastic 3D printing method with a twist is PolyJet. It is capable of fabricating pieces with multiple qualities, including materials and colors. The technology can be used by designers to prototype overmolded or elastomeric components. We advise sticking with SL or SLS if your design is made of a single, stiff material because it is more cost-effective. However, PolyJet can spare you from having to spend money on tooling at an early stage of the development cycle if you're prototyping a silicone rubber or overmolding design. This can save you money and speed up the iteration and validation of your design.

Digital Light Processing (DLP)

Similar to SLA, digital light processing uses light to cure liquid resin. The main distinction between the two technologies is that SLA uses a UV laser, whereas DLP uses a digital light projector screen. This leads to higher build speeds since DLP 3D printers can picture a whole layer of the construct at once. Although DLP printing is commonly used for quick prototyping, its increased throughput makes it appropriate for low-volume plastic part production runs.

Fused Deposition Modelling (FDM)

One popular desktop 3D printing method for plastic components is fused deposition modeling (FDM). Layer by layer, plastic filament is extruded onto the build platform by an FDM printer. It's a rapid and economical way to create physical models. In certain cases, FDM can be utilized for functional testing; nevertheless, the technology is constrained by the relatively harsh surface finishes and weak parts.

Evolution of 3D Printing in Medicine

In addition to new reimbursement strategies, regulatory involvement and support, and new workforce development and education programs in medicine, engineering, and technical support, these increasingly used applications—from anatomic models for medical training and surgical planning to guides to directly assist with surgery to permanent patient-matched implants—have all grown from the initial seeds planted thirty years ago. (Fig.1).

Fig. 1

Applications of 3D Printing

Used for preoperative planning and individualized preoperative care. This will result in a multi-step process that will identify the optimal therapy option by combining clinical and imaging data. According to a number of studies, preoperative preparation tailored to each patient may cut down on operating room (OR) time and minimize complications. Additionally, fewer postoperative stays, fewer reinterventions, and lower medical expenses could result from this (1). A physical 3D model of the desired patient anatomy can be given to the surgeon via 3D printing technology. This model can be used to precisely plan the surgical approach in conjunction with cross-sectional imaging, or it can be used to model custom prosthetics (or surgical tools) based on the anatomy of the patient (2). Furthermore, the 3D printing gives the possibility to choose before the implantation the size of the prostheses components with very high accuracy.

Customize surgical instruments and tools: 3D printing can be used to create unique surgical instruments, guides, and implants. As a result, the additive manufacturing process lowers the cost of customizing surgical instruments and prostheses (3).

Study of osteoporotic conditions: 3D printing can be helpful in verifying the patient's outcomes after a pharmaceutical treatment (4). This makes it possible to estimate the patient's bone health more precisely and make better surgical treatment decisions.

Testing different device in specific pathways: Reproducing various circulatory patterns to evaluate the efficacy of a cardiovascular system used to treat peripheral and coronary artery disease is a prime example. We can swiftly create prototypes of novel design ideas or enhancements to current technologies thanks to 3D printing (5).

Improving medical education: It has been shown that 3D-printed patient-specific models can improve performance and speed up learning while greatly enhancing trainees' confidence, management, and understanding in any field. Reproducibility and safety of the 3D-printed model in relation to cadaver dissection, the ability to model various physiologic and pathologic anatomy from a vast image dataset, and the ability to share 3D models across institutions—particularly those with limited resources—are the advantages of 3D printing in education (6). Anatomical details can be highlighted with 3D printers that can print in a variety of colors and densities.

Patient education: For the majority of healthcare providers, patient education is one of the most important aspects of patient-centered treatment. However, it might not be effective to verbally convey imaging data or to show patients their CT or MRI scans since patients might not fully comprehend how 2D images represent 3D anatomy (7). Conversely, by immediately displaying the anatomic model, 3D printing may enhance the doctor-patient relationship (8).

Improve the forensic practice: Using cross-sectional imaging, a 3D model might be utilized in the courtroom to clearly illustrate a variety of anatomic anomalies that might be hard for jurors to understand (9).

Bio printing: Additionally, implantable tissue modeling is made possible by 3D printing. Examples include the 3D printing of artificial skin to be transplanted into burn victims. Additionally, it can be used to test pharmaceutical, chemical, and cosmetic items (10). Another example is the replication of human ears using molds filled with a gel containing bovine cartilage cells suspended in collagen, or the replication of heart valves utilizing a combination of cells and biomaterials to control the stiffness of the valve (11).

Personalized drug 3D printing: The process of 3D printing medications involves creating a powdery layer that dissolves more quickly than regular pills. Additionally, it enables the patient's required quantity to be personalized (12).

Customizing Synthetic Organs: 3D printing could be a lifesaver by cutting down on the number of patients on the transplant waiting list (13). Pharmaceutical companies may eventually utilize bioprinted organs in place of animal models to assess the toxicity of novel medications (14).

In CHD (Congestive Heart Disease): DICOM data from CT scans was used to create the 3D models, which were then processed to produce myocardial and blood pool models. These models were then sectioned for in-depth comparisons as required (15). SLA technology (Shaanxi Hengtong Intelligent Machine Co., Ltd., Shannxi, China) was used to create the physical models using hard resin. The 3D models took about 7 hours on average to print and post-process (16). When utilizing CT and echocardiography to diagnose difficult cases of congenital heart disease, experienced doctors showed noticeably better diagnostic accuracy than students. The expert group's average diagnosis accuracy went from 88.75% to 95.9%, while the student group's increased from 60% to 91.6%, following the use of 3D models (17).

CONCLUSION

In order to transform healthcare, 3D printing in the medical industry and design must look beyond the box. The potential to treat more patients where it was previously impractical, to achieve positive results for patients, and to reduce the amount of time needed in the direct case of medical specialists are the three primary pillars of this innovative technology. To put it briefly, 3D printing allows "physicians to treat more patients, without sacrificing results." As a result, 3D printing has opened up a lot of opportunities and benefits in the medical industry, just like any new technology (18). However, to ensure its proper usage, it must be accompanied with current and updated legislation.

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