

3D Printing: A Search towards Revolutionizing Medical Sciences

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ABSTRACT

Changes in lifestyles are demanding changes in the technologies. Innumerable innovations are equally coming in healthcare field. One of the novel technology arisen is 3D printing which is being made use of not only in engineering field but also in medical sciences and healthcare. 3D printing in medical field is also known as bioprinting. 3D printing is a methodology to produce a 3D object by depositing and fusing different materials like powders, plastics, metals, ceramics, liquids and other printer-compatible substances, even living cells layer by layer. This paper throws an insight on various applications on 3D Printing which is expected to revolutionize health care. The medical applications has been classified into broad categories, fabrication of tailor made organs and transplants, production of artificial tissues for screening of drugs, creation of organ models for surgical preparations, development of prosthetics and designing of dosage forms. The 3D printing offers a high number of advantages over traditional conventional methods like cost-efficiency, high productivity, reduced time in fabrication and development of innovative products incorporating different sizes, designs and styles according to the needs of the person.

Keywords: *bioprinting, additive manufacturing, artificial tissues and organs, computer-aided design, implants, transplants*

1. INTRODUCTION

Year by year technologies are advancing and its changing the ways how we live. As people's demands and life style change, so is the demand for advancing the type of technology. Innumerable changes have been brought about with these continuous technological advancements. Human medicine and health sciences have also significantly improved. Doctors and medical students have also embarked on medical technological tools to carry out extensive research on human health problems and challenges. This extensive research has resulted into the development of new diagnostics, new surgical tools and drugs, and treatments which have helped in curing most challenging human diseases which can help in saving so many lives and to prolonged human lifespan. One of the novel technology which has come up in recent years is 3D Printing.

3D printing is the future productive technology for the construction of the products of our desired shape and size by using various printers which are efficient enough to produce the desired thing. It is constructed by mixing various types of materials such as plastic, metal ceramics, powders, liquids and also using our living cells in the coming future. In medical sciences, 3D printing is also known as the BIOPRINTING or Additive

manufacturing. 3D printing is the advanced technology of the future which will primarily be used to make the life of humans better and bring a great and effective change in how the technique of curing the patients will be changed in the coming future[1].

It's just the matter of time , that just like you save your extra money in your bank , one day you will be saving the extra heart or limbs , just in case you need to replace the old one with the new one. The applications and scope of 3D printing is gradually expanding. Various types of 3D printers are being used in the pharmaceutical and medical industries for developing suitable products. There are many blue print files stored in the CAD file (computer aided design file) and they are easily accessible for getting a suitable product. The products generated through the 3D printing are nearly identical to the actually manufactured products.

The medical applications ranges from manufacturing of surgical tools, production of artificial tissues and organs, organ models for surgeries, fabrication of various tailored tissues & organs meant for transplant, printing of radiographic images, development of medical devices, creation of artificial customized prosthetics like limbs for handicapped, formulation of drug dosage forms in pharmaceutical industry[2].

The concept of 3D printing got developed in 1980s & the outlines/models generated by the computer are made to come into practise and a specific or compatible material is chosen to form the multilayer new form of the product[3].

2. HISTORY & METHOD OF BIOPRINTING

In 1983, Charles Hull, qualified in Engineering Physics invented stereolithography. He was working on developing plastic objects using photopolymers at the Company “ Ultraviolet products in California”[4]. He and his colleagues made use of a laser to solidify a polymer material that comes out from the nozzle. A file format called .stl was developed by his team members that contained the information about the surface geometry i.e 3D shape of the object. This .stl file format interpreted the data in the CAD file. Later, in 1986, Hull founded 3D Systems to manufacture 3-D printers and the materials to go in them. Around 2 dozen 3D printing processes are known that uses different printer technologies. Their speeds and resolution varies and they can utilize about 100's of materials to develop a desired 3D object in any shape that can be imagined[5] .

3D printers by moving the pin-head along x-y plane, follows the instructions provided in the computer-aided design file to build the basic foundation for any object. Then the printer, by moving the pinhead along the z axis builds a particular object one layer by layer [6]

In medical technology, imaging techniques, like X-rays, computed tomography (CT) scans, magnetic resonance imaging (MRI) scans and ultrasounds are used to produce the original digital model, which are get stored in the 3D printing data collector.

3. ADVANTAGES OF BIO-PRINTING

The 3D printing offers various advantages over the actual manufacturing of products[7]

1. It gives freedom to make customized medical products, implants, devices etc. Various surgical tools prepared by this technique can be made use of in cases of surgeries which will automatically increase the success rate and may decrease the actual time required to perform a surgery.
2. Reduced Costs in the longer run: 3D printing is able to decrease the manufacturing costs as it reduces the need of unnecessary resources .
3. Increased Productivity: 3D printing is able to give the products much quicker than the traditional methods of developing implants, models, prosthetics etc. Most of them can be made within 24 hours.
4. Increase innovation. A person can imagine innumerable designs of the objects and make use of this technology to produce products. The colours and styles can be made according to a person preference.

4. USE OF 3D PRINTING IN MEDICAL SECTOR

4.1 Tailor made organs and transplants

The malfunctioning of the tissues and organs are the major problems as we get old. Due to the production of severe stress on these organs and with no source of maintenance, these are the problems faced by the people as they grow in age . Moreover, when there is an organ damage or failure, there is an urgent need of transplants/implants. The data of US showed that around 1,50,000 in 2014 cases were there waiting for the organ and many died due to the dearth of such implants [3,8,9]. Furthermore, the surgery is highly expensive, the follow up after surgery is also very costly and organs taken from donors are also not found to be compatible. Another disadvantage with traditional organ transplant is that the patient is also required to take medicines like immunosuppressants in order to avoid transplant rejection. So 3D printing becomes the alternative to the one in need, where the cells can be taken from the patient's own body and the cells can be developed in a required tissue. Without bio-printing, we will be still dependent on the donor organs which are not easily compatible at all.

The method to develop a tissue shall involve first to isolate the specific cells called stem cells , mixing them with growth factors, multiplying them in the laboratory and using scaffolds, helps in cell multiplication and differentiation into a particular tissue. Parameters like highly specific cell placement, resolution, speed , cell concentration, drop volume and diameter can be utilized in getting customized tissues through 3D printing[10] . Hip implants , dental implants are the field where 3D printing are proved to be effective and fast . Heart valve, Spinal disk, artificial ear, some types of cartilages and bones are also developed using 3D printing. Wang et al utilized this bioprinting technology to deposit different cells into different biocompatible gels and created an artificial liver [11-12].

4.2 MEDICAL RESEARCH

One of the important challenging aspect of drug discovery and development is to screen out the drugs i.e medicines first in animals and then in living human beings. Such type of trials require lot of money and time as well as life of individuals may come into danger. So in order to avoid these, the therapeutic potential medicines can be directly screened on tissues and organs made by 3D printing technique. The literature survey found that

3D printing has been able to produce structures like bones, exoskeletons, cell cultures, vascular networks etc. Researchers at Organovo have developed strips of printed liver tissue for screening novel drug therapies[13-14].

4.3 ORGAN MODELS FOR SURGICAL PREPARATION

Human body is a highly complex structure which requires detailed study before commencing any procedure or operation. Various operations and surgeries in the medical industries are sometimes very complicated and need to be attained with near perfection for a successful operation. 3D printing technologies can be used for the practice by the amateur surgeons as well as by the experienced one in difficult or complicated situations. The training on surgeries are normally given on the cadavers which are costly and sometimes not available. They also often lack appropriate pathology. 3D printed organ models will definitely greatly help in such cases as they represent some of the most complicated structures in the human body. Neurosurgeons have taken the aid of 3D printed neuroanatomical models for surgical planning in complicated situations. A 3D printed model a calcified aorta was developed to plan for surgical removal of plaque [4].

4.4 DEVELOPMENT OF PROSTHETICS

3D printing has assisted the prosthetic design and their production incredibly more affordable as well as accessible for those who do not have limbs. Traditional methods usually cost a prosthetic very high as it utilizes highly costly materials which result in significant financial burden on a family. The materials include polypropylene, polyethylene, acrylics, and polyurethane. There is also an internal structure called a pylon that is composed of a lightweight materials such as titanium, aluminum, or carbon fiber. Moreover, the prosthetics are required to be tailor made to fit that particular individual which requires sufficient time too, which can range from weeks or months. 3D printed prosthetics are very economical as they are mainly composed of plastic material. i.e acrylonitrile butadiene styrene (ABS) plastics . 3D printers are becoming compatible with other materials like lightweight titanium to increase durability and strength. Secondly, 3D printers are affordable and the ability for anyone to design and print custom design parts has made prosthetics radically more affordable and accessible to people all over the world.

3D printed prosthetics are of great use for children. Normally the average lifespan of a prosthetic is around 5 years, during that time a child grows so rapidly that he/she will be needing another prosthetic very frequently. Through 3D printing, the required artificial limb or any missing part can be made much quicker within 24 hours. The consumers can easily customize their purchases by picking up their favourite colours and styles to fit their wants and needs [15]. Researchers at Belgium successfully made the first 3D printed titanium mandibular prosthesis, using a laser to melt thin layers of titanium powders. Other prosthetics made are used for spinal disorder, dental and cranio-facial disorders. 3D printing has revolutionized hearing aid manufacturing. 99% of customizable hearing aids depending on the ear shapes have been created using 3D printing.

4.5 USE IN DEVELOPING DOSAGE FORMS AND DRUG DELIVERY DEVICES

The Pharmaceutical industries are making use of 3D printing in designing dosage forms having complex drug release properties. The drug name could be imprinted on the tablet or capsule. The design and the formulation can be made

suited to the needs of the persons. This shall especially benefit those patients whose pharmacokinetic profile varies due to their genetic make up. In such patients, the medicines seems to either produce unwanted effects or failure of therapy. Such people require personalized medicine where 3D printing can definitely contribute. By making different polymer matrices, the drug release profile and amount of drug released can be varied. Some examples of dosage forms built using bioprinting techniques and approved by FDA are solid dosage forms of prednisolone, nanoparticles of rifampicin, tablet of acetaminophen etc.[16-17].

5.FUTURE PRESPECTIVE OF 3D Printing

3D printing offers a tremendous scope . It's believed that this technology will serve like a sharp sword in the field of medical science which is cheaper , easy to operate and effective more than that of recent technology and will replace the organs , generate personal medications , implants , and produce more durable drugs at a cheaper cost. The technology will help the handicapped to replace its missing parts like arms, legs. With its growing trend, every operation for a surgeon becomes an easy and simpler task. In the medical universities, the students shall be trained on the complex artificial tissues instead of cadavers making them to understand the complexities of cell-cell interactions. Through 3D printing, the small incised cuts may be filled by using keratinocytes and fibroblasts aiding in complete repair process [18]. The technology will assist R & D in drug discovery and development to bring cost effective drugs in the market. Within 2 decades we can achieve the artificial functional heart which will be a major achievement in the field of medical science.

6.CONCLUSION

With use of more technological advanced 3D printers, more speed and resolution, the 3D technology is exploring newer applications. Gradually more and more materials are tried to being utilized with 3D printers to attain perfection in obtaining 3D structures. The researchers working in different universities are developing custom made products and drugs. Various organ models can be used for the latest drug discoveries in the coming future. BIOPRINTING is surely going to be a useful weapon by the medical industries, a weapon not for war but for peace among humans and relieving them from their pain and problems in the coming future. It can be concluded that 3D printing technology is indeed transforming medical sciences.

ACKNOWLEDGEMENT

We are very grateful to the Director Dr.(Col.) A.Garg and Joint Director, Dr. Manoj Goel, KIET Group of Institutions for their motivation and all round support. I also acknowledge Dr. Ranchey Bhateja and Dr.Mani Tyagi, faculty members of MBA department who inspired me to write this article.

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