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A Review Article on 3D Printing Technology and Its Medical Applications

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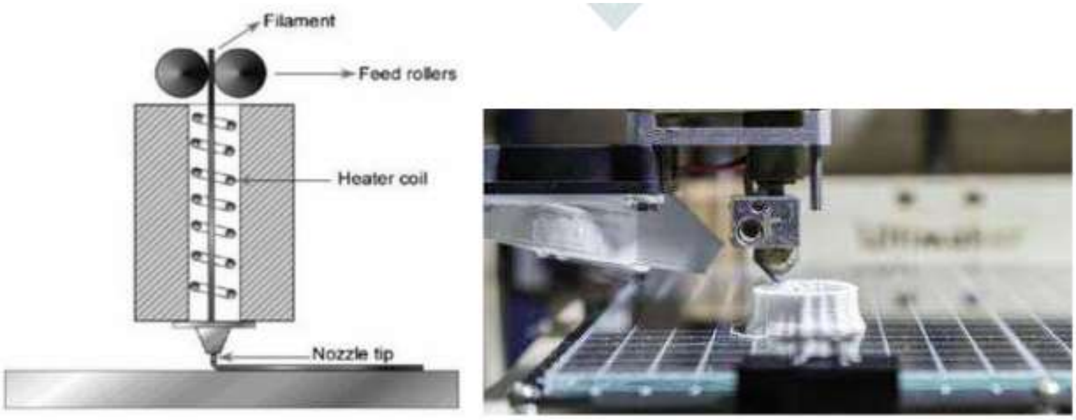
Abstract: 3D printing is a hot topic of today's technology discussion. A large number of research papers on additive manufacturing and its application in medical cases are published every year. A significant body of work from this will be examined and various applications of 3D printing in the medical field will be analyzed to provide the best and most reliable method for the development of scaffolds and biomedical implants. This study aims to show the advantages of 3D printing compared to traditional manufacturing methods. There are numerous applications of additive manufacturing in the different areas of today's world. The aim of the article is to show the 3D printing technology in medicine and its advantages alongside current and future applications. Conclusion: The article presents the literature review on the medical application of 3D printing and its future area of application. 3D medical models are reverse engineered to design and manufacture custom implants and bones. It has been adapted and modified to suit the patient's requirements. It can be different for each patient and can be changed. Compared to other manufacturing methods, it offers extensive benefits to mankind in a short period of time.

Keywords*: *3D printing, 3D scanning, Additive Manufacturing (AM), Implant, Scaffold, Biomedical material, Medical, Applications and Rapid Prototyping (RP)

1. INTRODUCTION

3D printing is a process of making a 3D object of the desired shape and size from a 3D model. This 3D model is created in CAD software or generated from scan data of a specific patient. It is an additive process where multiple layers are added under computer control. The additive manufacturing process is the complete opposite of the subtractive process, where material is removed from a block layer by layer, such as drilling, milling and facing. 3D printing begins in 1981. Dr. Hideo Kodama of the Nayoga Municipal Industrial Research Institute files the first patent for a rapid prototyping machine. First patent ever in this field by Dr. was registered. Shown is Kodama, which used a laser beam to solidify the resin. In 1986, Charles Hull of 3D System Corporation developed the first working 3D printer [1]. Charles Hull was a pioneer of solid imaging. Stereo lithography (STL), developed by Charles Hull, is still widely used in 3D printing. After the development of the first printer, the device is used more and more frequently in the field of technology and research. The machine price is lowered and becomes more affordable. In recent years, rapid prototyping has found a wide range of applications in the fields of research, aerospace, the medical industry, production engineering, architecture and the computer industry.

3D printing technology plays a crucial role in the medical field as it offers promising and close to the original quality for bone regeneration rehabilitation and reconstruction [2,3] and expands the treatment in the field of surgery[4]. Since then, many different processes and fabrication techniques have been developed that share the same goals to create 3D structures that mimic the internal and external geometric shapes of authentic structures [5] and provide essential structure for migration and cell attachment, thus stimulating tissue regeneration. On the other hand, such adapted and modified scaffolds act as filling and loading material that rehabilitates the affected sites. Tailored 3D scaffolds designed with signaling biomolecules and stem cells have recently been effectively implanted into targeted defects [6,7].



There are a group of technologies to describe 3D printing: rapid prototyping, solid freeform manufacturing and additive manufacturing. 3D technologies are about the development of a well-defined 3D shape from a computer-aided design model by layer-by-layer addition [8]. Medical imaging technology, particularly magnetic resonance imaging (MRI) and computed tomography (CT), provided the information for model design. The captured raw image data is refined and traced as a 3D model, which is then transferred to a 3D printer for execution. Computer-aided manufacturing methods are used to design and develop and reconstruct 3D objects based on anatomical information of the tissue. After that, scaffolding 3D printing began by adding layers of biological materials with tailored shape and internal porosity, reinforcing with biomolecules, and seeding cells in multiple combinations [9,10].

2. Manufacturing in medical field

There are significant manufacturing developments in the field of medical made by this technology.

a. Designing and development of bio implants.
b. Reducing operation time.
c. Developing lightweight and desired porosity implants.
d. Producing improved quality implants.
e. Achieving excellent surface quality.
f. Exact size, shape and matching of tailor made parts.
g. It providing pre surgerical planning to surgeons and it also helps the students for better understanding.
h. Provides substitution for the replacement of defected bones.

Hutmacher stated that there is a primary need for robust bone and osteochondral reconstruction methods that take into account certain factors such as biochemical, morphological and anatomical factors[11]. The bone in the defective area can be replaced with a new one. The required replacement bone can be produced using 3D printing. These bones replace the defective area. Hieu et al. generated the design data while processing medical images (Magnetic Resonance Imaging (MRI) and Computed Tomography (CT)) and presented the design method for carnioplasty implants using medical 3D printing technology. Reverse engineering methods are used to construct the 3D model. All of this is based on different types of data extracted from bone layer contours ((IGES) and (SSL)) and stereo lithography files (STL) [12]. This method is more helpful and advantageous for the design and manufacture of medical implants. He et al. Shown design and manufacturing process consisting of porous titanium alloy and bio ceramic application on 3D printing technology for a hemi knee joint. Reconstruction of the femoral bone was performed and accurately assessed using reverse engineering and CT Image. The deviation of 0.206 mm of the recreated 3D model from the original anatomy [13]. The result of the experiment shows that the bone substitute has good mechanical strength and fits well. Willis et al. explained that additive manufacturing is necessary for the generation of 3D objects from CAD models. 3D scanner is used to capture..

Hutchinson noted that the demand for custom bones and joints using additive manufacturing has increased due to spinal deformities, spinal cord injuries, osteoporosis, traumatic musculoskeletal injuries and arthritis. The use of 3D printed joints has increased in the medical field [15]. Esses et al. The illustrated 3D model, developed from CT data using 3D printing, has various clinical applications such as surgical communication and planning. Patients can communicate well with 3D models and the model is also used in prosthesis and surgery planning [16]. Van Noort defined that 3D printing makes surgical procedures cheaper, faster and more precise than manual methods. The cost of models made using 3D printing is low compared to models made using other methods. The accuracy of the 3D printed model is also high [17]. Evila et al. The research work focused on the development and manufacture of customized tracheal stents by 3D printing. With this automatic and innovative system, the overall efficiency in the production of customized tracheal stents is increased. The surface quality achieved in this research work is excellent and the manufacturing costs have also been reduced [18]. Abraham et al. stated that 3D printing developed all human parts. Many plastic surgeons prefer fat structure grafts. With this method, both aesthetic and reconstructive interventions can be archived without any problems. This technique is worthwhile for soft tissue augmentation [19]. Mishra stated that 3D printing technology is used to develop custom sizes of...

3. Advantages

a. Low Production time: direct production starts from the 3D CAD model mean that no moulds and tools are required for the starting. Production time from design to the final product is quite low. 3DPrinting develops the product very fast as compared to conventional methods. Production time reduced from months to days with the help of 3D- Printing.
b. Affordable: With the 3D-Printing products are produced at much faster rates. Product development costs reduced considerably. The production run cost of this process is quite low.
c. Feedback and evaluation: Prototype developed with this technique is tested under various circumstances. It sells on various online sites and gets customer response for the betterment of the product.
d. Easily Shearing: the saved data file of the design is easily shared worldwide in lesser time. It also facilitates the sharing of knowledge and modification of design with the help of

experts from different parts of the globe.

e. Material Wastage: As the process is additive in nature the wastage of material is very low. Hollow part and holes are directly produced in produced. it saves the materials as well as machining cost also.

f. Complicated design: Manufacturing of complicated design and contour shapes are easy with 3DPrinting. Streamline shapes are also manufacture easily with this process.

g. Small batches: Small batches and customized products are economical with this production method as compared to traditional methods.

4. Disadvantages

a. IP rights: Replica can be created very easily using 3D technology raises the issue over intellectual property rights. Blueprints of components available free of cost online. That may be edited and modified and used again.

b. Small Size: Components manufactured by 3D-Printing is limited by sizes now a day. The feasibility of large components is very less.

c. Limited raw material availability: Now a day a large number of smart materials are available. Many of which are not suitable for 3D-printing.

d. The use of this smart material is increased day by day. More research is required to find the usability of such material in the field of manufacturing.

e. Printer cost: the initial investment cost of 3D-Printer is very high. It is not feasible for small or average householders. Different printers are required for a different types of materials and different types of components. Manufacturing of color components is also costlier than monochrome objects.

f. Loose of manufacturing jobs: With the advancement in technology and automation in production manufacturing jobs will decrease. it has a large impact on the economy of the country, especially countries that require low skill jobs.

5. Application

a. This technology is assisting in custom made implants for the patient which is less required and differ for every patient.

b. It fulfills the need easily, in less time and at affordable prices.

c. The accuracy of different implants made for a different patient is very good and the surface finish is also very good.

d. The model production with the help of this technology is fast. No tooling and fixtures for this technology.

e. Researchers successfully print ears. Skin kidney, bones and blood vessels with the help of this technology.

f. Houses are also printed with the help of this technology.

g. The complex shapes of aeronautics and aerospace industries are easily formed with high accuracy. With modern conventional methods manufacturing of these is very difficult and accuracy is also very low.

6. Conclusion

3D printing is changing and revolutionizing the world. The production of individual implants is very easy and inexpensive with 3D printing. This allows a high level of accuracy and surface quality to be achieved. It is a very fast and reliable method in the field of medical science. Also, the cost of customized parts is lower compared to other methods. This technology is also proving beneficial in some critical patient conditions. The production of scaffold tissue and bone should be considered promising with this technology. 3D printing offers extensive support in medical applications. It also explores new markets to help humanity.

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