A review paper on 3D-printing technology and its application medical field

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Abstract

3D-printing is a hot topic of today's technological discussion. A large number of research papers have been published every year on additive manufacturing and its application in medical cases. A significant number of papers from that are studied and various applications of 3d-printing in the field of medical analyzed for delivering the best and reliable method for the development of scaffolds and biomedical implants. This study will illustrate the advantages of 3D-printing as compared to conventional manufacturing methods. Numerous application of additive manufacturing is represented in the different field of today's world. The paper aims to show the 3D-Printing technology as being utilized in medical and its advantages alongside present days and future applications.

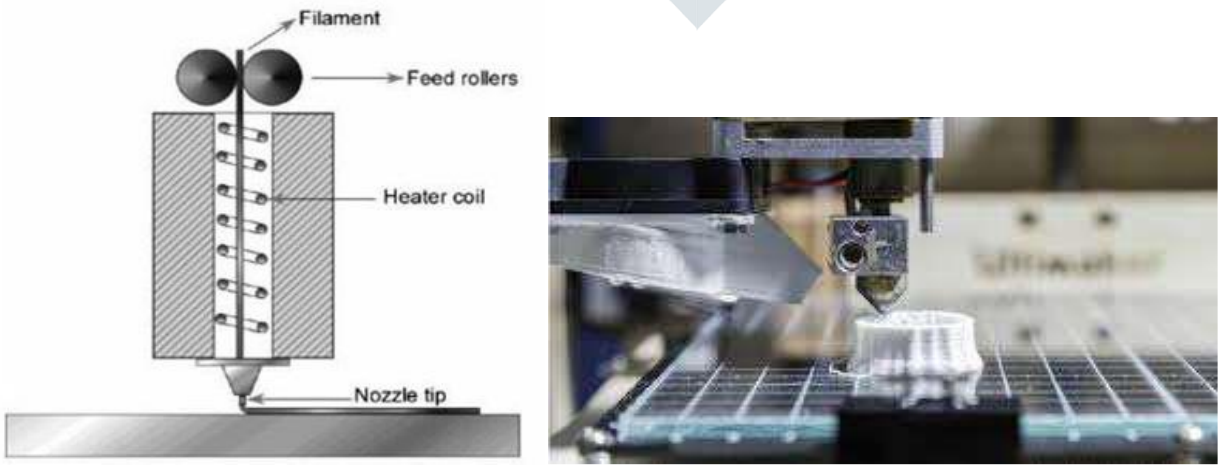
Conclusion: Paper presents the literature review of Medical application of 3-D Printing and its future scope. 3-D medical models are prepared with reverse engineering to design and manufacturing of customized implants and bones. It modified and customized as pre patient requirements. It may be different for every patient and can be modified. It provides the extensive benefits to humanity in short time as compared to other manufacturing processes.

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 for making a 3D object of desired shape and size from the 3D model. This 3D model is prepared in CAD software or generated from scan data of a specific patient. It is an additive process in which several layers are added under computer control. The additive manufacturing process is totally opposite from the subtractive process, where the material is removed from a block layer by layer such as in the case or drilling, milling and facing. 3D-printing starts in 1981. Dr. Hideo Kodama of Nayoga Municipal Industrial Research Institute patent first application for rapid prototyping machine. First ever patent filed in this field by Dr. Kodama in which a laser beam was used to resin solidifying is depicted. In1986 Charles hull of 3D System Corporation developed the first working 3D printer [1]. Charles hull was a pioneer of the solid imaging process. Stereolithography (STL) developed by Charles hull is still widely used in 3d printing. After the first printer was evolved the machine becomes more and widely used in the field of engineering and research. The machine price is lowered and becomes more affordable.

In the last few years, rapid prototyping has a wide range of applications in the field of research, aerospace, medical industry, production engineering, and architecture and computer industries.



3D- Printing technology in the field of medicine plays a vital role, by offering promising quality and close to the original one for bone regeneration rehabilitation and reconstruction [2,3] and extending treatment in the

field of Surgery[4]. Since then, many assorted procedures and manufacturing techniques have developed, in viewing the same objectives to produce 3D structures that emulates the internal and external geometrical shapes of authentic ones [5] and deliver essential structure for migration and call attachment, thereby inciting tissue regeneration. On other hand such a customized and modified framework function as filling and loading material that renovate the impaired sites. 3D tailored made scaffolds developed with signaling biomolecules and stem calls, have lately been effectively implanted into targeted defects [6,7].

There is a group of technology for describing 3D-Printing: Rapid prototyping, solid freeform fabrication and additive manufacturing. 3D technologies involve in the development of well defined 3d shape from designed computer aided design model by layer-by-layer addition [8].

The medical imaging technology, especially magnetic resonance imaging (MRI) and computer tomography (CT) provided the information for model designing. The captured raw imaging data are refined and retraced as a 3D-model, which is then transferred to 3D printer for the execution.
Computer aided manufacturing methods are used to design and develop 3D objects, based upon anatomical information of tissue, to reconstructed. After that scaffolds 3d-Printing started by adding a layers of biological materials, with tailored shape and inner porosity, enhanced 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 an primary requirement of robust bone and reconstruction of osteochondral methods which takes into account certain factor like biochemical, morphological and anatomical[11]. Defected area bone can be substituted with new one. The substituted required bone can be manufactured with the help of 3D-printing. These bones replace the defected area. Hieu et al. generated the design data during the processing of medical images (magnetic resonance imaging (MRI) and computer tomography (CT)) and represented the design method of carnioplasty implant employing medical 3D-printing technology. To construct the 3D model reverse engineering methods is used. All this is based on different type of data extracted from bone slice contours ((IGES) and (SSL)) and Stereo Lithography files (STL) [12]. This method is more helpful and advantageous for the design and manufacturing of medical implants.

He et al. represented designing and fabrication process composed of porous titanium alloy and bioceramic relaying on 3D-Printing technology for a Hemi- Knee joint. With the help of reverse engineering and CT Image the rebuilding of femur bone was made and precisely judged. The deviation of 0.206 mm of 3D rebuilt model from original anatomy [13]. The result of the experiment shows that substitutes bone has good mechanical strength and matches well. Willis et al. stated that additive manufacturing is necessary for the generation of 3D objects from CAD models. 3D- Scanner is used to capture and extract the model data. This digital model data was processed, modified and the prototype is developed with the help of3D-Printing [14]. High accuracy is attained for deep concavities and complex shape of developed object.

Hutchinson found the demand of tailor made fabricated bone and joint with the help of additive manufacturing has increased due to spinal deformation, spinal code injuries, osteoporosis traumatic musculoskeletal injuries and arthritis. The use of Joint manufactured with 3D-Printing has increased in the field of medical [15]. Esses et

al. explained 3D model developed form CT data with 3D-Prinitng has various clinical applications like surgical communication and planning. Patient are communicated well with 3D models and the model also used in prosthesis and surgical planning [16].

Van Noort defined 3D-Printing makes surgery cost effective, faster and accurate than manual process. The cost of model manufactured with 3D-Printing is low as compared to model developed by other method. The accuracy of 3D printed model is also high [17]. Evila et al. research work focused on designing and manufacturing of tailored tracheal stent by 3D-printing. The overall manufacturing efficiency of tailored tracheal stent is increased with this automatic and novel system. The surface quality achieved during this research work is excellent and manufacturing cost also reduced [18].

Ibrahiem et al stated 3D-Printing developed all human parts. Many plastic surgeons give preference to fat structural graft. With this method both aesthetic and reconstructive surgery is archived easily. This techniques is a worthwhile for soft tissue augmentation [19]. Mishra stated 3D-Printing technology is used to develop custom sizes valve to the patient. Biological material can be used for the development of valve by 3-D printing, it could grow with patient. Soft and elastic material was used to create 3-D shape by biomedical engineers which truly matched heart epicardium [20].

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. 3D-Printing 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 3D-Printing. 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 reshapes and revolutionized the world. The manufacturings of custom implants are very easy and cost effective with 3D-Printing. With this high accuracy and surface finish can be achieved. It is very fast and reliable method in the field of medical science. The costs of tailor made parts are also less as compared to other methods. This technology is also proves beneficial in some critical condition of patient. The manufacturing of scaffolds tissue and bone should be considered as promising with this technology. 3D-Printing provide extensive support in medical application. It is also exploring new market to help humanity.

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