

Review Article

3 –D Printing - Beyond Innovation

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Abstract

Advances in the field of computer, prototyping and imaging especially over last 10 years, have led to the adaptation of 3-D printing, which has various applications in various fields which includes medical field, dental field and engineering field. It is one of the recent advances which would be very much useful for the betterment of society. This article reviews the basic principle, various application and advantages of 3-D printing.

Key words: Additive manufacturing, Stereolithography, CAD-CAM technology, Basic principles of Rapid prototyping.

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Introduction

3D printing is a method of manufacturing objects in which materials, such as plastic or metal are deposited in layers to produce a three dimensional object.¹ In the past few decades they have quickly developed into a new paradigm called additive manufacturing.² 3-D printing is an additive printing process; the technology is based on ink-jet principle and can print with a variety of materials. The technology uses computer aided design (CAD) file which is processed through specialized software and spliced into a series of two-dimensional layers. The printer produces the object layer-by-layer with support from a water-soluble material.²



Figure 1: Cube X Trio- 3D Printer
Picture courtesy: Department of Maxillofacial
(Department of Prosthodontics, Saveetha Dental College, India)

History:

History of rapid prototyping dates back to 1770 in which mechanization was first introduced, and in 1946 first computers were introduced by Charles Babbage, in 1952 first numerical control (NC) machine tool came to play. And in 1963 first interactive system (early version of computer aided design) was used and in 1988 first commercial rapid prototyping system was used.³

Basic Principles of 3d Printing/ Rapid Prototyping:

Regardless of various techniques 3D printing describes 3 basic principles

- 1) A model or a physical part which is to be built should be modeled on a computer-aided design-computer-aided manufacturing (CAD-CAM) system. The model should be represented as a closed volume that means the data must specify the inside, the outside and the boundary of the model; this ensures that all horizontal cross-sections that are essential to rapid prototyping are closed curves to create the solid object.
- 2) The surface model to be built is converted into stereo Lithography (STL) file format; this file format approximates the surface of the model by polygons. Highly curved surfaces must employ many polygons, which mean the STL file format will be large for curved parts.
- 3) A computer program analyzes an STL file that defines the model to be fabricated and “slices” the model into-cross sections. The cross-sections are systematically recreated through the solidification of either liquid or powders and then combined to form a 3D model.⁴

Various Systems of Rapid Prototyping:

- Liquid based rapid prototyping system- Stereo lithography apparatus (SLA)
- Solid based rapid prototyping system- Fused Deposition modeling (FDM)
- Powder-Based rapid prototyping system- 3D system’s Selective laser sintering(SLS).⁴

A few important rapid prototyping processes namely stereolithography (SL), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), and Laminated manufacturing (LOM) are discussed in detail.

- 1) Stereolithography is a layer by layer 3-D model production system in which the model can be produced from various ultra-violet photo-polymerizing resins by laser-fusion.
- 2) In Selective Laser Sintering (SLS), thin layers of heat fusible powders such as polycarbonate or glass-filled composite nylon are relatively fused .This enables the direct fabrication of wax prototypes for development of facial prosthesis which can be sterilized by epoxyethanal and which can be recycled,
- 3) Fused Deposition Modeling (FDM), which builds the model by depositing layers of molten thermoplastic materials.
- 4) Laminated object Manufacturing (LOM), which creates 3-D models by laminating adhesive coated sheets of paper in which the adhesive is heat-activated by a focused laser beam.
- 5) Solid Ground curing, which laser polymerizes successive layers of resin through a stencil
- 6) 3-D Ink-jet printing, which selectively deposits binding material through a print head to fuse a thin layer of metal or ceramic to a

previously fused layer and then fired in a furnace for sintering.^{5,6,7}

Applications of Rapid Prototyping:

Medical Field:

With the use of highly sophisticated imaging system accurate diagnosis can be made which is of utmost importance in treatment planning.

Surgical Field:

Surgical field is an area where 3D printing technology has a greatly influence. Using 3 D printing technology and CT scanning pre operative planning can be easily done for certain high-risk surgeries like cardiac surgery. Unlike generic medical replica, which is not a good representation of a structure, 3D printed models are accurate and since it's designed for an individual person, it aids in better understanding of the anatomy and improves surgical success rate.

The benefit of computer assistance for surgeons in the operating theater includes intraoperative planning, according to available data. The initial data is obtained from various scanning modalities like CBCT, dental model scan and facial surface image. This information is then transferred to the network for storage and manipulation, and finally the system produces Patient-Specific Anatomic Reconstruction (PSAR) and the treatment planning is completed finally, the data is sent directly to the surgical team for surgical guidance and assistance.^{8,9}

Educational Purpose:

Anatomical relation are always difficult to understand, but with the use of advanced imaging modalities like CT, surface imaging and serial sections better understanding can be achieved.

Now a 3D model can be built based on virtual prototypes by means of Computer Numerical Control (CNC) device. Computer can now accurately create detailed models that can be accessed from various aspects in a process known as computer-aided Design (CAD). To materialize virtual object using CAD, a computer aided manufacturing (CAM) process has been developed to transform a virtual file into a real object, CAM operates using a machine connected to a computer, similar to a printer or peripheral device.¹⁰

Dentistry:

Dental coping are one of the major success stories of AM application.

The implementation of 3-D printing in dentistry solves some of the problems common in traditional dentistry.

The old days when a patient went to a dentist office-the dentist has to go into patient mouth to take impression of mouth to construct crowns, bridges and implants. But now with the emergence of rapid prototyping technology two-minute digital scan of a patient entire set of teeth is made. Once the information is captured by the intra oral scanner the dentist passes around the teeth, it is delivered to a dental lab where milling or 3-D printing machine are used to craft the artificial dentition, most of which is made from zirconium dioxide.

Due to the fact that the printed product is produced by a normal CT scan, dentists can select which portions they want to printed and are able to scale them accordingly. A CT scan, is a series of X-rays that are performed at various angles. When compiled the X-rays create a 3-D image. With this technology, it is now possible to print not only teeth but also the jaw, mouth facial reconstruction.^{11,12}

Prosthetic Field:

With accurate precision and light weight construction, 3D printing for prosthetics is ideal for amputees to improve their lifestyle.

Maxillofacial prostheses are usually fabricated on the models obtained following the various impression procedures which have many disadvantages. Thus rapid prototyping has a potential to simplify the procedure. It eliminates the need for measurement impression procedure and decreases the laboratory procedures involved.

There are various methods for the manufacture of prosthesis, they are

- 1) Hand sculpturing method
- 2) Impression of a similar organ and wax modeling with this impression
- 3) Rapid prototyping techniques^{13,14}

Since the conventional methods need more experience and time for lab work, rapid prototyping is the choice of treatment, it uses images obtained by computer tomography, magnetic imaging or laser surface scanners. These procedures have been called as computer aided design (CAD). Computer Aided Manufacturing (CAM) is production of this 3 dimensional model by rapid prototyping technology.

Rapid prototyping consists of two main stages which includes virtual stage and physical stage. Virtual prototyping is formation of models by dynamic and interactive simulation. Process of forming the physical model is by (CAD). This process allows the production of geometrically complex shaped models. These models can be used to duplicate the missing organs.^{15,16}

Orthodontic Field:

Custom made brackets for orthodontic purpose are an ideal target for additive manufacturing technique.

Conventionally the protocol for fabrication of oral appliances like removable orthodontic appliance, bite splints and sleep apnea appliances, includes alginate impressions and wax registration taken by the dentist and the appliance made by the dental technician. Three-dimensional computer-aided design (3D-CAD) creates new possibilities in this field allowing greater use of industrially manufactured appliances while respecting the biological tissue reaction in the dental tissue.¹⁷ Computer-aided graphical 3D-reconstruction has been used to trace the prenatal development of the human temporomandibular joint.¹⁸ Clear orthodontic aligners provide a way to move the teeth with an aesthetic removable appliance in patients with only minor orthodontic problems or the aligner can also be used as a finishing or retention appliance.

The advantages of this removable appliance were faster production, inexpensive and more precise. A study conducted by Mika salmi, jukka tuomi, and Antti makitie on rapid tooling method for soft customized removable oral appliances aimed at describing the process of manufacturing customized oral appliances with a new technology ie, rapid tooling method, The study used stereolithography technique and silicone material and created a customized soft orthodontic appliance with adequate accuracy.¹⁹

Advantages of CAD/CAM Technique:

- 1) Elimination of disturbance due to the impression material because there is no need to take impression material because there is no need to take impression.
- 2) Possibility to form the form the model by avoiding deformation of the tissue due to the use of techniques that do not

required contact such as CT or laser surface scanner

3) Possibility to obtain more realistic looking prosthesis because the model is formed from nature tissues.^{5, 20-23}

Conclusion

Rapid prototyping, additive manufacturing, 3 dimensional printing technology is becoming a common application within many industries such as manufacturing and medicine. As more research is being to develop 3 D printing is rapidly becoming an affordable technology that has the potential to change not only the future of fabricating medical models and prototyping but also society.

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