Heal Talk

3D Printing- The New Frontier in Prosthodontics - A Review

Dr. Rashmi Agarwal[1], Dr. Swati Gupta[2], Dr. Subodh Shankar Natu[3], Dr. Sarita Seth[4], Dr. Rohie Jawarker[5]

Reader[1,3], Professor[2], Consultant[4],PG Student[5], Department of Oral & Maxillofacial Surgery[1,3,4,5], Department of Prosthodontics[2], Babu Banarasi Das College of Dental Sciences, Lucknow

Abstract

The Prosthodontics work always been considered as tedious, laborious and time consuming. But in the 21st century innovation in the field of machining and digitalization has made the work of prosthodontics much easier, simpler and faster. The most widely acceptable example of this technique has been used of CAD-CAM (computer aided design- computer aided machine). This concept also has had its share of deficiencies. The new concept of 3D –printing exhibits the potential to overcome these deficiencies and present itself at the fore front of prosthodontics art and science. 3D-printing employs an additive manufacturing process whereby products are built on a layer-by-layer basis, through a series of cross-sectional slices. 3D-printing can be used not only produce fixed partial dentures which may be both meta and ceramic based restorations(crown, inlays and onlays) but also complex restoration like removable partial denture and maxillofacial prosthesis. But still evidence base research is required to validate this revolutionary concept of technology.

Key words: 3D printing, CAD-CAM technology, Stereolithography, Rapid prototyping, Fused deposition modelling, Inkjet Printing.

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Introduction

The prosthodontics work always been considered as tedious, laborious and time consuming. But in the 21st century innovation in the field of machining and digitalization has made the work of prosthodontics much easier, simpler and faster. It gave chance to life became easier. Although various materials and technique were developed in the laboratory dental field, the conventional metallic manufactured by lost wax technique is still used .This old technique is successful however it's inherited drawbacks. This conventional technique is time consuming; require multiple steps and technique sensitive.This more steps used more chance for errors and ill fitting denture. The CAD CAM (computer aided design – computer aided machine) technology became one of the most important developments happened in dental field at the twenty first century.This concept is also has had its share of deficiencies.[1]The new concept of 3D-printingexhibits the potential to overcome these deficiencies and present itself at the fore front of prosthodontics art and science.

What is 3D Printing and how does it work?

3D printing is a form of additive manufacturing technology where a 3 dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanised method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing the blueprints for object.3D filters are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D scanner. The basic principles include materials cartridges, flexibility of output, & translation of code into visible pattern.

Definiton

3D + Printing = 3D Printing

3D printing is a phrase used to describe the process of creating three objects from digital file using a materials printer, in a manner similar to printing images on paper (figure - 1).

History of 3D Printing

The earliest 3D printing technologies first became visible in the late 1980's, at which time they were called Rapid Prototyping (RP) technologies. As an interesting aside, the very first patient application for RP technology was filed by a Dr Kodama, in Japan, in May 1980. In real terms, however, the origins of 3D printing can be traced back to 1986, when the first patient was issued for stereolithography apparatus (SLA). This patent belonged to one Charles (Chuck) Hull, who first invented his SLA machine in 1983. In 1987, Carl Deckard, who was working at the University of Texas, filed a patent in the US for the Selective Laser Sintering (SLS) RP process. 1989 was also the year that Scott Crump filed a patent for Fused Deposition Modelling (FDM. The FDM patent was issued to Stratasys in 1992.[2]

2012 was the year that alternative 3D printing processes were introduced at the entry level of the market. As a result of the market divergence, significant advances at the industrial level with capabilities and applications, dramatic increase in awareness and uptake across a growing maker movement, 2012 was also the year that many different mainstream media channels picked up on the technology. 2013 was a year of significant growth and consolidation.[3]

How does it work?

A person creates a 3 Dimage of an item using a computer aided design (CAD) software program. The CAD information is sent to the printer. The printer forms the item by depositing the material in layers – starting from the bottom layer – onto a platform. In some cases light or lasers are used to harden the material.

Basic principles of 3D printing

Step 1 (Cad File is Created) -

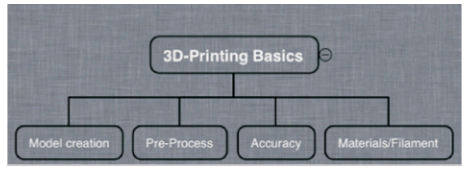
A model of the object is created on a computer. Software analyses this model, taking a series of cross-sections & working out the distributions of space & solid matter within each layer.

Step 2 -

The CAD file is exported to a 3D printing machine.

Step 3- Actual Object-

Once each layer is complete, the build tray is lowered by a fraction of a millimeter and the construction of a new layer begins. When all the layers have been completed, any excess material is cleaned away to reveal the finished object.



Currently, 3D printing technology is used to provide a number of products in the dental industry. Most common are wax pattern for fixed prosthodontics and models fabricated from intraoral or impression scans.

There are Different 3D Printing Technologies Being Used in Dental Industry Today-

A. Stereo Lithography Apparatus (SLA)
B. Selective Laser Sintering (SLS)
C. Fused Deposition Modeling (FDM)
D. Laminated Object Manufacturing (LOM)
E. Inkjet 3D printing

A. Stereo Lithography Apparatus (SLA)

This type of 3d printing was presented by Hull in year 1984, for the production of 3d models fro photopolymers resins. This system consists of both of photosensitive liquid resin, a model building platform and an ultraviolet (UV) laser for curing the resin. The layers are cured sequentially and bond together to form a solid object beginning from the bottom of the models and building up.

As the resin is exposed to the UV light, a thin well defined layer thickness becomes hardened. After a layer of resin is cured, the resin platform is lower within the bat by a small known distance. A new layer of resin is whipped across small known distance. A new layer of resin is wipped across the surface of the previous layer using a wiper blade, and this second layer is subsequently exposed and cured. The process of curing and lowering the platform into the resin bath is repeated until the full model is complete.The self adhesive property of the material causes the layers to bond to each other and eventually form a complete en bloc 3D object. The model is then removed from the bath and cured for a further period of time in a UV cabinet(figure- 2).

Advantages

· Good speed.

- The length of time – depends on the size and complexity of the project.
- Maximum size of approx 50X50X60 cm.
- Prototype made by it are strong enough to be machined and can be used as master patterns for injection molding, thermoforming and various metal casting processes.

Disadvantages

- Very expensive.
- The cost of photo curable resin ranges from $80 to $210 per litre.
- Cost of achiness ranges from $10lac to $5lac.

B. Slective Laser Sintering (SLS)

It is an additive manufacturing technique that used for the low volume production of prototypes models and functional components. It was developed and patented by Dr. Carl Dackard and Dr. Joe Beaman in the mid 1980s. It involves the use of a high power laser to fuse small particles of plastic, metal, ceramic or glass powders into a mass that has a desired three dimensional shape.

The laser selectively fuses powdered material by scanning cross- sections generated from a 3D digital description of the part on surface of a powder bed. After each cross-section is scanned, powder bed is lowered by top, and the process is repeated until the part is completed. SLS machine preheats the bulk powder material in powder bed below its melting point by infrared heating in order to minimize thermal distortion (curling) and facilitate fusion to the previous layer. Various materials can be used such as fine polymeric powder –polysterene, polycarbonate or polyamide etc. Withinthe range of 20 to 100 micrometer diameter. The laser is modulated in such away that only those grains, which are in direct contact with the beam are affected (figure-3). The ability of this technology to build up removable partial denture (RPD) frameworks has been demonstrated. The part proved successful and produced a complete cobalt chrome RPD framework.

The possibility to preheat the SLS machines just below the temperature needed for metal powder sintering (melting) by lasers made this system very speedy. This minimizes thermal distortion and facilitates fusion to the previous layer.

Advantages

- In this process support structures are not required as the un-sintered powder remains at the places of support structure. It is cleaned away and can be recycled once the model is complete.
- Using selective laser sintering is that it can give 100% density and drawbacks are the cost.

C. Fused Deposition Modelling (FDM)

FDM is the second most widely used 3D printing technology, after stereo lithography. Aplastic / wax filament is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off.

The nozzle is mounted to a mechanical stage which can be moved in both horizontal and vertical directions. As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic/wax to form each layer. The plastic/wax hardens immediately after being squirted from the nozzle and bonds to the layer below . the entire system is contained within a chamber which is held at a temperature just below the melting point of the material.(figure-4)

Advantages

- The FDM process allows a variety of modelling materials and colors, such as medical grade ABS, poly-carbonates and investment casting wax.
- FDM are that this process gives direct wax patterns, and is fast and speedy. on the negative side it can be used only with thermoplastic materials, it gives rough surface and is 100% dense.
- FDM can produce models, as well as surgical guides and templates, out of medical grade ABS, Which is gamma-sterilisable and translucent.

D. Laminate Object Manufacturing (LOM)

It is a rapid prototyping system developed by Helisys. In it, layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing. Typical layer resolution for this process is defined by the material feedstock and usually ranges in thickness from one to a few sheets of copy paper.

Laminated Object Manufacture (LOM) cuts the component slices from thin layers of material using a CO_2 laser mounted on a 2D plotter. The system most commonly uses sheets of paper stacked on top of another automatically and bonded together using an adhesive. The parts of the sheet outside the model provide support. These unwanted areas are marked with intersecting lines, which forms cubes that can be broken away from the model once complete. (figure-5)

Advantages

- Components do not need support structures.
- Only the circumference of the part is processed, whilst in most RP methods the whole part area needs to be processed.
- A potential for high manufacturing speeds.

Disadvantages

- Producing good bonds between layers.
- Poor surface finish.
- Difficulty in producing hollow parts.

E. Inkjet 3D Printing

The working principle of this 3D printing system is basically similar to he conventional 2D inkjet printers. This machines uses a single jet is for a plastic build material and a wax like support material, which are held in a melted liquid state in reservoirs.

The liquids are fed to individual jetting heads with squirts tiny droplets of the materials as they are moved in X-Y fashion in the required pattern to form a layer of the object. The materials harden by rapidly dropping in temperature as they are deposited. After an entire layer of the object is form by jetting, a milling head is passed over the layer to make a uniform thickness.

Particles are vacuumed away as the milling head cuts and are captured in filler. The process is repeated to form the entire object. After the object is completed, the wax support material is either melted or dissolved away. The most outstanding characteristics of inkjet system is the ability to produce extremely fine resolution and surface finishes, essentially equivalent to CNC machines. The technique is very slow for large object (figure-6).

Advantages

- Direct inkjet printing of dental prosthesis added of zirconia direct inkjet printing.
- A cleaning unit anda drying device allowed for build –up of dense components of the size of a posterior crown.
- The novel technique has great potential to produce cost efficiently, all ceramic restoration at high accuracy and with a minimum of materials consumption.

3D Printing in Dentistry

As in many branches of medicine, 3D printing has been also used in dentistry for a range of dental specialities, including oral and maxillofacial prosthodontics and surgery, dental impolantology as a surgical guide or pyysical model and prosthodontics.

The use of 3D printing in dental branches has many other benefits of which only one of them is medical modelling construction, there are so many useful fields in which 3D printing can be helpful. i.e. mass production of patterns for casting purpose. In this way, time consuming and/or difficult parts in restoration making can be easily implemented even without human intervention.

Uses in Dental Field

(figure- 7)

- Dental copings are one of the major success storage of CAM application.
- With accurate precision and light weight construction, 3D printing for prosthetics is ideal for amputees to improve their life style.
- Maxillofacial prosthesis are usually fabricated on the models obtained following the various impression procedures which have many disadvantages thus 3D printing has a potential to simplify the procedures to create maxillofacial prosthesis.
- Generalised procedure for creating dental models.

Recent Advantages of 3D Printing in Dentistry

(figure- 8)

- Implant dentistry
- Creation of temporomandibular joint models for diagnosis and consulting patients with TMJ disorders
- Reduction of storage space as teeth and jaw models can be scanned and archived digitally rather than having to store physical copies

- Creation of mouth guards, stents and splint.

Uses in Medical Field

- 3D printed cast help to repair broken bone. Which may be the future of medical orthopaedic cast
- They can use to print the part of the hand. This was without finger.
- 3D- printing of cells nano particles, creating the biomic ear.
- It can make the replica, which are ideal for dry runs of complex operation allowing the surgeon to see before hand the exact anatomical landscape they will have to navigate.
- 3D printer that uses living cells to print out a transplantable kidney.

Advantages of 3D Printing

- Speed is the obvious benefit of 3D printing.
- Quickly delivers a better design communication tool, the physical prototype quickly and clearly communicates all aspects of design.
- Facilitates the early detection and correction of design flaws.
- It gives designer the ability to quickly turn concepts into 3D models or prototypes.
- Clean process: Wastage of material is negligible.
- Complex shape can be produced.
- Easy to use and No skilled person needed.
- Reduce design complexity.
- People in remote locations can fabricate objects that would otherwise be inaccessible to them.

Disadvantages of 3D Printing

- Process is slow.
- Components do not have enough strength.
- Cost of raw materials.
- 3D printers are still expensive.
- Misuse of technology.
- Although 3D printers have the potential of creating many jobs and opportunities, they might put certain jobs at risk.

Future of 3D Printing

With today's 3D printers, if you loose your TV remote's battery cover you can print a replacement battery cover. With tomorrow's, if you loose your remote, you'll be able to print a new remote.3D printers are always getting cheaper and better. There is currently research going on to create 3D printers that could print our organs for people in need of a transplant.Within a decade, 3D printers will become a commonplace in house.The benefits of such technology are endless.

Conclusion

3D printing is an emerging field in the fields of dentistry. It is relatively new technology and thereare no restrictions on industry. Its significant decrease in product development cycle & costs and Full effects on business & society still not know. It is noteworthy that working with these technologies in the medical/ dental field differs considerably from using them in the industrial environment. 3D printing, 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 3D printing is rapidly becoming an affordable technology that has the potential to change not only the potential to change not only the future of fabricating medicine as well as dental models and prototyping but also society.

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