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3D PRINTING TECHNOLOGY AND APPLICATIONS IN PROSTHETIC DENTISTRY – A REVIEW ARTICLE

Dr. Jaykumar Gade, Professor and Head, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Dr. Sayali Nikode, Post Graduate Student, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Dr. Karan Jaiswal, Post Graduate Student, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Dr. Ravina Khairkar, Post Graduate Student, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Dr. Roshni Taori, Post Graduate Student, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Dr. Sharwari Bhatkar, Post Graduate Student, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Corresponding author: Dr. Jaykumar Gade, Professor and Head, Department of Prosthodontics, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

Abstract: Nowadays, 3D printing is frequently depicted in the media as a technique that is commonly used to create dental prosthetics. It is an advanced manufacturing technique, often known as additive manufacturing. It involves creating things using a sequence of cross-sectional slices, layer by layer basis. It is built on digital computer-aided design (CAD) models, which employ standardized materials to produce customized 3D things using certain automation procedures.

The work of prosthodontist has historically been viewed as time-consuming, arduous, and unpleasant. Digitization has made the practice of prosthodontics a lotsimpler, quicker, and easier because of digitization.This article tries to review, using true data, how 3D printing may now be utilized in prosthetic dentistry and in dental labs.The paper also explores future views and looks at the continued feasibility of conventional dental laboratory services and

production methods. Furthermore, it demonstrates the knowledge required for the digital additive fabrication of dental restorations.

Keywords: 3D Printing, RP- Rapid prototyping, Stereolithography, 3D inkjet printing

Introduction: Change is the law of life and those who look only to the past or present are certain to miss the future." And the future is Digital dentistry. The phrase "Digital Dentistry," which describes the rising use of digital technology in dentistry, has gained much popularity over the years. Dental practise has evolved beyond the traditional two-dimensional (2D) approach of dental professionals to include the most recent and advanced three-dimensional (3D) technique in creating a unique treatment experience for patients looking for speedy and high-quality outcomes.[1,2] The usage of 3D printers is one such technology that is poised to drastically change the manufacturing process. This technology is also termed as "additive manufacturing", "layered manufacturing" "rapid prototyping" and "freedom fabrication" has been replacing certain manufacturing previously performed by subtractive manufacturing.[3] The use of 3D printing has increased over past few years drastically in many fields ranging from aerospace, eco-friendly buildings to life saving medical implants, and even artificial organs using layers of human cells are created.Its uses in dentistry range from prosthodontics, oral and maxillofacial surgery, and oral implantology to orthodontics, endodontics, and periodontology.[4] The flexible use of 3D printing enables the creation of completely automated, custom treatment programmes, providing patients with individualised dental tools and assistance.[5]The aim of the present paper is to make a review about the usage and applications of 3D-printing technologies in prosthetic dentistry.

History: Early in the 1980s, the first commercially available additive manufacturing (often known as 3D printing) systems hit the market. Charles W. Hull; S. Scott Crump; and Hans J. Langer and Hans Steinbichler, are some of the pioneers of 3D printing.[6] Since the invention of the first three-dimensional (3D) printing technology by Charles Hull in 1986, the manufacturing industry has developed a wide range of production processes that are applied in several industries.[7] The Massachusetts Institute of Technology (MIT) patented "3D printing techniques" in 1993.At the time, the main use of 3D printers was for rapid prototyping.But technology advanced swiftly in the years that followed. In 2009, when the patent on the fused deposition modelling (FDM) method expired[8], 3D printers made substantial progress towards reaching the consumer market. Finally, this dynamic had an impact on the dental sector.Printing units became smaller and less expensive, and their area of application changed. Plastics, metal, ceramics, and even human tissue have all become materials for 3D printing.(9)

What is 3d Printing: 3D printing is the automatic process of creating a three-dimensional object by adding material rather than taking it away. It works on principle of additive manufacturing whereby multiple layers of material are laid down to produce a three-dimensional object. 3D printers are devices that print digital data in layers to create real-world 3D objects. It can create physical models of items that were either created using a CAD programme or 3D scanned.

Prototype Generation: A person uses a computer-aided design (CAD) software programme to build a 3D picture/ model of an object to be created. On a computer, a model of object is made. Software evaluates this model by obtaining a number of cross-sections and figuring out how much space and solid matter need to be distributed within each layer. STL file is generated accordingly then the 3D printing device receives the CAD information. By depositing the material onto a platform in layers, beginning with the bottom layer, the printer starts creating the object. After each layer is finished, the build tray is lowered by a fraction of mm, and work on the next layer starts. After each layer is finished, any extra material is removed to show the final product. Sometimes the material is hardened using light or lasers.

The dentistry sector already offers a variety of items thanks to 3D printing technology. The most popular models are those made from intraoral or impression scans, as well as wax patterns for fixed prosthodontics. Different 3D printing technologies are now being employed in the dentistry.(10)

1. Stereolithography apparatus (SLA)

2. Selective Laser Sintering (SLS) or Selective Laser Melting (SLM)

3. Fused deposition modelling (FDM) or Fused filament fabrication (FFF)

4. 3D inkjet printing (3DP)

5. Laminated object Manufacturing (LOM)

Stereolithography Apparatus (SLA) [12]

Charles W. Hull introduced stereolithography in 1984 for the creation of 3D objects using photopolymer resins. The components of stereolithography systeminclude a model-building platform, a bath for photosensitive liquid resin, and an ultraviolet (UV) laser for curing the resin.[11] The procedure includes building up models; the layers are gradually cured and bonded together to make a solid object. After exposure of resin to UV light, a well defined layer of minimum thickness gets hardened. As the layer of resin gets cured, the platform lowers down by minute’s distance. Using a wiper blade, a new layer of resin is wiped over the surface of the first layer, and afterwards the second layer is exposed and cured. Up until the whole model is finished, the curing and lowering of the platform into the resin bath are repeated. The layers finally join together and create a whole en bloc 3D object with the help of self-adhesive property of the material used. The object is then taken out of the bath and given another UV cabinet curing session.[12]

Material type: Liquid (photopolymer)

Material used: Thermoplastics (elastomers)

Advantages

1. This technique can print a wide range of materials.
2. Good speed.
3. Sustainable accuracy and precision.

Disadvantages

1. High cost of material.
2. High machine maintenance due to laser components.
3. Complex post print processing.
4. Time consuming.

SELECTIVE LASER SINTERING (SLS) OR SELECTIVE LASER MELTING (SLM)[13]

It is an additive manufacturing technology that was first discovered and developed at the University of Texas in Austin by Dr. Carl Deckard and Joe Beaman in the middle of the 1980s.

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Layers of a specific powder material are fused together into a 3D model using a computer-guided laser.It fuses tiny powdered pieces of plastic, metal, ceramic, or glass into a mass with a specified three-dimensional shape using a powerful laser. The material is distributed evenly over a construction cylinder's surface by a roller. On top of the prior hardened layer, powder is applied layer by layer and repeatedly sintered. The supporting platform reduces one item layer thickness to hold the new, fresh layer of powder. Then a laser beam hits the powder's surface after it has been tightly crushed. The process is self-sustaining, and layer-by-layer bonding is possible for all components. The piston is lifted to elevate the item after it has fully formed. Extra powder is readily brushed off, and final hand finishing can be done.(14)

Material type: Powder (Polymer)

Material used: Thermoplastics such as nylon, polyamide, polycarbonate, polystyrene, elastomers or composites, etc.

Advantages

1. Low price of machinery components.
2. A wide range material can be printed.
3. Material can be recycled.

Disadvantages

1. High Machine maintenance dur to laser component.
2. Large parts cannot be manufactured precisely.
3. High melting temperature.

FUSED DEPOSITION MODELLING (FDM) OR FUSED FILAMENT FABRICATION (FFF)(12)

After stereolithography, FDM is the second most popular 3D printing technology. FDM was given by Stratasys in Eden Prairie, Minnesota.It involves layer-by-layer extrusion of plastic or wax along a nozzle that follows the cross sectional geometry of the component. The construction material is typically provided in filament form, although some may use plastic pellets.The plastic is heated in the nozzle to melt it, and there is a mechanism that controls the flow of the molten plastic.The mechanical stage on which the nozzle is attached may be adjusted both horizontally and vertically. Each layer is formed by the deposition of a thin bead of extruded plastic or wax as the nozzle is moved over the table in the necessary shape. As soon as it leaves the nozzle, the plastic or wax hardens and adheres to the layer below. The complete apparatus is housed in a chamber that is kept at a temperature slightly below the material's melting point.

Material type: Solid (filaments)

Material used: Thermoplastics such as ABS, polycarbonate, and polyphenylsulfone; elastomers

Advantages

1. Available for variety of modelling materials.
2. Fast and high speed.

3D Inkjet Printing (3DP)[(12)]

It uses the additive rapid prototyping procedure also known as "Powder bed and inkjet" and "drop-on-powder" printing. This system works similarly to that of conventional 2D inkjet printers. 3DP is a layer-by-layer process that is continued until the prototype is fully constructed. This machine has a single jet for a wax-like support material and a plastic construction material, both of which are kept in a reservoir in melted liquid state.

The procedure begins with the built material, i.e.thermoplastic and support material i.e. wax kept in a melted condition inside a two headed reservoir. Each material is fed into an inkjet print head, which moves in the X-Y plane and squirts small droplets of ink into the appropriate spots to create one layer of the component. Both the building and support materials immediately cool and solidify. A milling head travels across a layer after it has been finished to smooth the surface. The particle collector vacuums up the debris created by this cutting action. To build the next layer, the platform and its parts are lowered down by an elevator.The process is repeated until the entire object is formed. Once the object is formed, the remaining support material is either melted or dissolved away.

Material type: Liquid.

Material used: Thermoplastics such as polyester.

Advantages

1. High precision and efficiency.
2. Extremely fine resolution and surface finish.

Disadvantages

1. The technique have very slow build-up speedfor large object.
2. Not useful for impression purpose.
3. Very few material options.
4. Have fragile parts.

Laminated Object Manufacturing (LOM)(15)

Laminated object Manufacturing (LOM) was initially created by Helisys of Torrance, CA. which included systematically sticking together layers of adhesive-coated paper, plastic, or metal laminates together and providing them a shape with a knife or laser cutter. The system is based on a feed mechanism in which a sheet movesover a built-in platform, a heated roller topressurize the sheet to adhere on the layer below, and a laser to cut the shape of the part in each layer of sheet. Stacking, glueing, and cutting layers of adhesive-coated sheet material on top of the preceding one, preparation of parts is done. The contour of the component is cut into each layer with laser. After finishing each cut, the platform lowers by a depth equal to the sheet thickness, and another sheet is advanced on top of the previously placed layers. The platform then raises slightly and the heated roller exerts pressure to bind the fresh layer. The outline is cut by laser and until the part is finished, the same process is repeated.A layer is then sliced and extra material stays in situ to provide support to the component during construction.

Material type: Solid.

Material used: Thermoplastics such as PVC; Paper; composites (ferrous metals; non-ferrous metals; ceramics)

Advantages

1. Support structures are not required.
2. High speed.

Disadvantages

1. Poor surface finish.

2. Hollow parts cannot be produced.

Applications in Prosthetic Dentistry

1. **Wax Pattern Fabrication:** The process of fabricating a dental prosthesis begins with the creation of a wax pattern.[15] Making the wax pattern traditionally is the most difficult but important phase in creating porcelain-fused-to-metal crowns, pressed ceramic crowns, and RPD frameworks.[16]The fabrication of quality wax-up is time-consuming procedure. Therefore, with the development and acceptance of RP technology, a novel method for automated wax-up production is now feasible. It involves three steps: 1. 3D optical scanner is used to digitise the master model.2. CAD software is used to design the wax pattern. 3. Wax pattern fabricated using RP.[17-19]
2. **Crowns and Bridge Fabrication:** Crowns and Bridges can be fabricated using resin-based 3D printing technologies such as SAL or SLS,[20] etc. When compared to milling, the amount of materials utilised in 3D printing processes is lower, with nearly no material loss.[21]It can print many materials simultaneously with good detail repeatability. It's important to have a proper marginal and internal fit to ensure the soft tissues mechanical stability, longevity, and health.[20]Insufficient sealing of restoration can cause microleakage, edge discoloration, plaque accumulation, lack of esthetics, tooth sensitivity, caries and periodontal disease.[22]
3. **Removable Partial Denture Frameworks:** With the help of an Intraoral scanner and CAD software, the framework for a removable partial denture can be fabricated using 3D printing technology more accurately and quickly, as the conventional steps can be replaced by digital method.
4. **Complete Denture Fabrication:** Without using moulds, cutting tools, or tooling fixtures, 3D printing technology may swiftly create a new digital model from intraoral scan and CAD data and can be used to fabricate a complete denture resin foundation.[23] The advantages of 3D printing include faster manufacturing of dentures with fewer clinical and lab steps, which can reduce the likelihood of human errors.[21] The use of 3D printing in the creation and design of complete dentures is still under research.

5. **Implantology:** Since the introduction of the Osseointegration, the utilisation of dental implants has advanced quickly. For individuals who are partly or fully edentulous, viable and predictable restorative alternatives have been developed as a result of advancements in the field of oral implantology.Proper implant placement is a crucial aspect. The success and long-term predictability of the implant-supported prosthesis might suffer from improper implant placement.(16)

   In implant dentistry, the use of computer-aided design (CAD/CAM) technology has gained popularity in recent years. Rapid prototyping is used in implantology to plan treatments in 3D using 3D scans and software.Laser sintering and direct beam melting are two 3D printing techniques that are frequently utilised to create customised porous implants, surgical guides and templates, and customised 3D printed trays for implant impressions.(25)

6. **Maxillofacial Prosthesis:** Facial prosthesis moulds can be made using rapid prototyping as an alternative to the traditional flasking and investment processes. This contemporary method of creating face prostheses streamlines the procedure and enables many pouring from a single mould.

   In maxillofacial prosthesis, 3DP is used for:

   1. Fabrication of orbital, auricular and nasal prosthesis.
   2. Obturators can be fabricated.
   3. Fabrication of surgical stents for patients scheduled for excision of large tumours.
   4. It is especially important to duplicate an existing maxillary or mandibular prosthesis when an exact fit to natural teeth or an osseointegrated implant is required, etc

Advantages of 3D Printing:

1. Accuracy is one of the most important advantages of 3D Printing.
2. Speed is the obvious advantage of 3D printing.
3. Aids in the early identification and rectification of design problems.
4. As works on additive manufacturing technique, there is minimum wastage of material.
5. Complex designs can be manufactured in no time.
6. Simple to use and requires no special expertise

Disadvantages of 3D Printing:

1. Very high cost of raw materials.
2. Expensive machineries.
3. The cost of 3D printers is still high.
4. 3D printing is very slow process for large objects.
5. Despite the fact that 3D printers have the potential to provide a large number of employment and opportunities, certain occupations may be at risk.

Conclusion: The application of 3D printing has increased recently in field of dentistry, but its applications in prosthodontics are still rare.The most frequent use is to create functioning models for surgery and diagnostic purpose, followed by a range of implantable devices that can assist dentists in providing patients with more predictable, minimally invasive, and less expensive procedures.Manufacturing dental prostheses will never be the same again, thanks to 3D printing.To apply any new technology in day-to-day life,having knowledge of it is very important. This article discuss the detailed techniques used for 3D printing technology and its application in Prosthetic dentistry.

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