Review Article

3D Printing in Prosthodontics-A Review

Abstract: The profession of prosthodontics has always been significantly impacted by technical advancements, and 3D printing is no exception. The fabrication process produces complex shapes with ease and is highly precise, time- and labor-efficient. A kind of digital fabrication process called additive manufacturing uses the addition of materials to create actual objects from a geometric model. It begins by introducing the most recent 3D printing methods, such as fused deposition modeling , photopolymerization molding, and powder bed fusion. It also provides a number of variables that affect 3D printing metrics, including accuracy and mechanical qualities.A description of the clinical uses of 3D printing in dentistry, including the creation of working models and main applications in the fields of prosthodontics.

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INTRODUCTION

Charles Hull unveiled the first three-dimensional (3D) printing technology in 1986, the manufacturing sector created a extensive range of production techniques that have been used in a wide range of industries. Hull created and developed a 3D printing method and obtained the stereolithography (SLA) patent in 1986. An advanced manufacturing technique is three-dimensional printing, often known as additive manufacturing. Its uses in dentistry span from orthodontics, endodontics, and periodontology to prosthodontics, oral and maxillofacial surgery, and oral implantology[1]. From fabrication using the lost wax process to production utilizing CAD CAM technology, dentistry has improved. The raw materials are machined into the appropriate shape and geometry in this subtractive process. Owing to this method's numerous drawbacks, additive manufacturing, or 3D printing, was developed. According to the American Society for Testing and Materials (ASTM), additive manufacturing, as opposed to subtractive manufacturing techniques, is the process of connecting materials to produce items from 3D model data, often layer by layer. This operates on the idea of making a number of cross sectional slices from a 3D computer file. Using 3D printers, each slice is printed one on top of the other to produce the three-dimensional object with the benefit of minimum waste[2]. According to several research , 3D printed restorations have edge and internal gap values that are much lower than those of milled restorations. The direct approach of scanning is a product of the technology's long evolution and gets rid of all the drawbacks of impression materials currently in use as well as the possibility of a mistake in the lab. Digital impressions are exceptionally accurate, dimensionally stable, and patient-friendly. Despite their distance from one another, communication between the dental clinic and the laboratory has never been so simple. The process is simplified to only sending a file by this practice[4].

ADDITIVE MANUFACTURING

Using digital data from the computer, the additive manufacturing method constructs parts layer by layer from the bottom up[6]. Throughout the preceding 20 years, additive manufacturing has been extensively studied. Charles W. Hull introduced it to the world in 1984. Many polymers, metals, ceramics, and composite materials are employed in 3D printing. The seven additive manufacturing processes identified by ASTM include material extrusion, binder jetting, material jetting, powder bed fusion directed energy deposition, sheet lamination, and vat photopolymerization[3].

Photopolymerization Process

A liquid polymer resin is used in photopolymerization, an additive manufacturing method, to build 3D structures.. By using a UV laser to cure a photopolymer resin, this method creates prototypes, models, and patterns. Several grades of polymers are the materials used in this method. The most often employed technology in this process is stereolithography (SLA). Charles Hull invented SLA in 1986. To prevent the object from being deformed, some of the structures in this process might require a support network. Sharp tools can be used to remove these supports, which are constructed from the same material as the part. The finished component is cleaned in a chemical solution to remove any extra resin, and then it is cured in a UV oven [3,6].

Extrusion-Based Systems

Plastic prototypes and low volume functional parts are produced using extrusion-based technologies. Fused Deposition Modeling, an extrusion-based method, is the most popular technique(FDM). S. Scott Crump created the extrusion-based FDM technology in the late 1980s for use in prototyping, modelling, and production applications. In this process, modelling material is used to create the finished item, and support material is used to create the temporary support material[3,6].

Powder Bed Fusion Processes

To melt and fuse tiny powder particles to create 3D objects, the powder bed fusion method uses either a laser, thermal energy, or an electron beam as the energy source. A wide variety of materials, including polymers, metals, ceramics, and composites, are used in this procedure .Several sorts of procedures are employed in this process, including direct metal laser sintering (DMLS), selective heat sintering (SHS), electron beam melting (EBM), selective laser melting (SLM), and selective laser sintering (SLS) [3,6].

Material Jetting Process

Inkjet print heads are used in the material jetting process to discharge material droplets onto the build platform layer by layer as the 3D item is constructed. These procedures create 3D sstructures using inkjet and other printing technologies. It is possible to print an item using various arrays of print heads and different materials. For the objects with complex geometries made up of overhanging structures, support structures are constructed. The object can be removed from these supports by submerging it in a water-based liquid. Because of their viscous character, polymers are frequently utilised as materials in this procedure [3,6].

Binder Jetting Process

In the binder jetting technique, a liquid binder and a powder substance are combined to create a three-dimensional structure. With the use of a variety of materials, including metals, composites, ceramics, sand, and polymers, this method may create pieces with any geometry. Binder jetting, or 3D printing, was developed in 1993 at the Massachusetts Institute of Technology. The remaining unbound powder serves as the object's support framework. When compared to other AM methods, this one can print items with solid layers and is more affordable [3,6].

Directed Energy Deposition

The directed energy deposition technique, powder is deposited and fused with a laser, electron beam, or plasma arc at the same time to create a part. Using this method, a metal structure can be constructed, or an existing component can be repaired or given new functionality. Several metals are used, including steel, stainless steel, titanium, nickel, and cobalt alloys .One method employed in this AM process is Laser Engineering Net Shaping (LENS). Through the use of metal powder and a powerful laser beam, this procedure was designed to create metal objects with intricate geometries from CAD data[3]. Sheet Lamination Processes the AM technique of sheet lamination, items are created by joining sheets of material. Paper, plastic, and metals are the materials used in this procedure.The sheets are joined together using a variety of processes, including adhesive bonding, heat bonding, ultrasonic welding, and clamping The two primary methods used in this procedure are laminated object manufacturing (LOM) and ultrasonic additive manufacturing (UAM). Helisys Inc. created LOM. In LOM, a plastic material is laminated layer by layer under pressure and heat before being laser-cut into the desired shape. advantages against other AM processes Sheet lamination is quick and efficient in terms of cost. Because there is no chemical reaction, large objects can be formed. The accuracy of the parts is not as good as the SLS method, and the object's polish depends on the material employed. LOM has applications across a wide range of sectors [3,6].

TYPES OF 3D PRINTING

FDM-Fused Deposition Modelling

In 1986, Mr. Scott Crump made the initial introduction of this kind of 3D printing technology.

A thermoplastic filament coil serves as the input material for this technology. ABS is the substance most frequently utilised in FDM (Acrylonitrile Butadiene Styrene). This procedure involves heating a certain thermoplastic filament to its melting point within an extruder, after which it is extruded layer by layer in a specific layer-by-layer configuration to create a 3D solid item[3].

SLS- Selective Laser Sintering

Powder is used as a raw material in the process of sintering, which involves heating the powder to a temperature slightly below its melting point. In this, a 3D object is made using polymeric powder. Thermoplastic, ceramic, glass, metal, and other materials are among those that can be utilised as raw materials in the selective laser sintering process. Nylon 11 and Nylon 12 are utilised in plastic, which accounts for the majority of the material used. A CO2 laser is utilised in SLS, and the user's computer is connected to the laser. Powder is heated inside chambers to just below its melting point after the laser tracks the precise geometries, and this particular powder is then fused together.

SLA- Stereo-lithography

The first 3D printing method ever introduced to the public was stereolithography. This specific method may turn the liquid resin polymer 3D printed pieces into solid ones. In this process, there are four crucial elements. First up is the tank's supply of UV Curable Photopolymer Liquid.

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The perforated table is the second one. The computer, which directs the movement of the laser source and perforated table, is the third component, and the laser source is the final one [3].

LOM- Laminated Object Manufacturing Using paper, plastic, and metal, the additive manufacturing technique known as laminated object manufacture (LOM) is used to produce 3D items. With this method, paper or plastic laminates are piecemeal bonded together and then laser-cut into the appropriate shape. In this method for producing laminated objects, a heated roller is used to first connect a sheet to a substrate, and a laser is then used to outline the model's or prototype's desired dimensions [3].

SDL-Selective Deposition Lamination

At the start of the procedure, a piece of paper is spread out on the platform. Glue is selectively sprayed on the paper, with a higher concentration in the working region and a lower concentration in the support area, respectively, to ensure that the support may be removed without difficulty. At the following stage, a paper feeding mechanism covers the freshly adhered sheet with a brand-new sheet. A study is conducted on the levels that "justify" the term "selective deposition lamination" in order to analyse SDL more completely.

- Selective: By improving glueing in the working region while reducing it at the aid position, the machine makes aid deletion simpler.

The LOM process applies adhesive to the entire sheet of paper, making it challenging to remove.

- Deposition: Using a paper cutter to apply adhesive, such as SLS, is an art that demands precision.

LOM glueing, in which glue is applied to the entire sheet, is done more consistently.

- Laminates: Laminates are sheets that have been piled on top of one another in layers.

These parts are made of paper, so they will survive for a very long time[3].

APPLICATION IN PROSTHODONTICS

It is undeniable that 3D-printing holds enormous promise for prosthesis because it allows medical professionals to prepare, scan, and manufacture dental prosthetics in a single session while yet maintaining clinical relevance. It is possible to create accurate virtual models of the teeth using intraoral or extra-oral scanners. Using CAD software, treatments and restorations can be created. A variety of dental restorations can be milled or printed using the scanning and CAD design data [1] A study was carried out by Bibb et al. to evaluate the efficacy of a technique that integrated CAD with 3D printing utilizing the selective laser melting method (SLM). It was possible to digitally create the RPDs components after a 3D scan of the partially dentate patient's cast was completed.

Crown and bridge denture

Interim crowns are a fixed denture's transitional phase that should meet all mechanical, biological, and aesthetic standards. Dentures with crowns and bridges can be created utilizing resin-based 3D printing techniques like SLA or DLP. The amount of materials utilized in 3D printing processes is lower than in milling, with nearly no material loss. To ensure the mechanical stability, robustness, and health of the surrounding soft tissues, a good fit is crucial.

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Excellent edges and internal fit were discovered in temporary crowns created using 3D printing, which are more precise than temporary crowns created using CAD/computer-aided manufacturing (CAM) or conventional milling techniques[1].

Complete denture

Without the use of molds, cutting tools, or tooling fixtures, 3D printing technology may swiftly construct a fresh digital model from CAD data and use it to fabricate a complete denture resin base. Complete denture bases can also be made using classic heat-curing and self-curing techniques, subtraction technology, and 3D printing technology. Compression molding technique and polymethylmethacrylate (PMMA) have both been used extensively. The advantages of 3D printing include quicker manufacture of dentures and fewer phases in the labour process, which can lower the risk of errors.. According to Tasaka et al., the photopolymerization spray-fabricated complete denture foundation is more precise than the thermal polymerization-based version. Yoon et al. examined the flexibility of the tissue surface between CAD/CAM complete denture foundation (5-axis milling or DLP generation) and traditional packaging pressing technology (PAP). The findings demonstrated that the DLP denture base's maxilla adaptability was marginally superior to that of the milling or PAP denture bases. Denture base materials used in 3D printing have lower mechanical qualities than most milling denture base materials and thermally polymerized acrylic resin [1]

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Removable partial denture

The production of removable partial denture (RPD) frames has new additive and subtractive process options because to rapid advancements in CAD/CAM. First, traditional casts or impressions are scanned using either an intraoral or extra oral scanner to create a digital work file, such as a standard tessellation file (STL). Second, STL files are sent to CAD software for designing, and then 3D printers are used to create unique structures. The risk of long-term bone resorption is decreased by using 3D printing technologies to construct RPD, which allows the denture base to give more uniform contact pressure [1].

DISCUSSION

This study discusses several forms of 3D printing and its uses in the prosthodontics industry. Applications for 3D printers include everything from creating wax patterns to mass producing dental implants with intricate geometries. SLS/SLM technologies can duplicate the intricate features, making them popular tools for creating RPD and FPD frameworks[3]. A study by Presotto et al. examined whether SLM technology offers more dimensional accuracy for 3-unit FPD frameworks than subtractive manufacturing and conventional casting. The findings revealed that SLM-produced frameworks outperformed casting- or milling-produced ones in terms of dimensional stability and precision. Co-Cr alloys and stainless steel were used to

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construct RPD frameworks using SLM, according to Bibb et al the production of crowns, temporary restorations, resin patterns, and try-in mockups are the principal applications for SLA and DLP[14]. SLA was employed by Wu et al and Kattadiyil et al. to create resin patterns for Co-Cr RPD frameworks. The fabrication of a custom-designed zirconia implant employing DLP technology is also demonstrated in a case study. These zirconia implants showed excellent surface roughness and dimensional precision. Cheng et al conducted a similar investigation. Custom dental implants were created in this study using zirconia ceramic particles. Research claim that bespoke trays and anatomical models are made utilising FDM technology. Another study states, ear prostheses have been effectively created using rapid prototyping and CAD modelling techniques. A mirror image of the other ear was created utilising scanning technology and utilised to create the mould using fused deposition modelling. Using customary lab techniques, silicone prostheses were created. Several 3D printing technologies are required due to the broad variety of materials used in prosthodontics. SLS/SLM can be used to build metal frameworks for repairs. SLA, DLP, and material jetting techniques enable better fabrication of wax patterns and tooth colour restorations. There is still little use of additive manufacturing in the prosthodontics industry. To use diverse 3D printing processes in the field of prosthodontics, more clinical research is needed.[2]

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CONCLUSION

The benefits of 3D printing broaden the scope of its dental applications. Future additive technologies will undoubtedly replace some steps or maybe the entire process of traditional methods of production. Despite the fact that 3D printers are getting more affordable, it is still important to take into account the materials used, maintenance costs, requirement for qualified operators, and tight health and safety regulations. To expand the range of clinical 3D printing applications in the prosthodontics discipline, further research needs to be done.

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