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3D PRINTING IN INTERDISCIPLINARY DENTISTRY

Dentistry

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ABSTRACT

3D printing, an additive manufacturing approach, has revolutionized dentistry in several significant ways, enhancing both the efficiency and precision of dental practices. The technology enhances treatment by enabling precise, customized solutions. Computer-aided design (CAD) is integrated with 3D printing technology. CAD receives the drawings and instructions, and uses them to instruct the printer to build the product three-dimensionally layer by layer. The integration of 3D printing not only streamlines workflows but also enhances patient outcomes, making it a valuable tool in modern dental practices. Right from the production of accurate models for day-to-day crowns and bridges, 3D printers may help in rapid production of custom devices, reducing the wait time for patients. Customized aligners, and surgical guides for implant placement with high accuracy can be produced easily. The use of 3D printing has quickly spread to a number of fields, including tissue engineering and regeneration, the creation of prosthetics and anatomical materials, and the development of drug delivery systems, in dentistry.

KEYWORDS

Stereolithography, rapid prototyping, digital light processing

INTRODUCTION

Over the centuries, dentistry has come a long way from its most primitive treatment options to modern solutions that can rehabilitate any patient in less than an hour. This has become possible with the advent of Computer-aided designing and Computer-aided manufacturing (CAD/CAM). The integration of natural and artificial intelligence has made unimaginable things possible for both dentists and patients.

CAD/CAM as a whole can be broadly classified into subtractive and additive manufacturing. Subtractive manufacturing involves the milling of the desired restoration from a pre-fabricated solid block. Additive manufacturing involves construction of a three-dimensional object by subsequent addition of layers of the desired material into the shape of the restoration, and has been termed 3D-printing as well. Even though both these manufacturing processes are poles apart, they require a basic Computer-aided design, to be made into reality.[1]

History

In the early 1970s, 'liquid metal recorder' was the first ever patented three-dimensional printing device, in the US, which was a continuous inkjet metal material device to form a removable metal fabrication on a reusable surface for either immediate use or salvaged for printing again by remelting.

During the time of early additive manufacturing technology, around 1980s, these techniques were predominantly considered suitable only for the production of aesthetic or functional prototypes, and was termed **rapid prototyping,** where three-dimensional plastic models were manufactured with photo-hardening thermoset polymer. Further in the decade, came into light the first ever computer automated manufacturing systems, and stereolithography followed it.

In the 1990s, metallic additive manufacturing processes such as selective laser sintering, direct metal laser sintering, and selective laser melting entered the market. As time progressed into 21st century, additive manufacturing became popular in large scale industries as well, and the use of this technology became more common. [2]

3D printing technologies and materials

In dentistry, we have access to volumetric data like Cone-Beam computed tomography, and intraoral scan data. CAD software allows us to create objects from scratch, in STL file format. Combining such data to design and produce useful apparatus is one of the key factors in application of additive manufacturing in dentistry. [2,3]

Stereolithography (SLA, SL) – This technology uses a light sensitive polymer, which is cured layer after layer, by a scanning laser, in a vat of liquid polymer. Despite the rapid fabrication and high feature resolution, the photopolymerizable resin comes with a limited vat and shelf life, which cannot be heat sterilized either.

Photopolymer jetting (PPJ) – light sensitive polymer is jetted out from an inkjet type of printhead, and cured layer by layer, on a build platform, which descends incrementally. This system comes with the advantage of being available in various colours and physical properties. It is relatively fast, and is capable of producing high resolution and high-quality finish. However, removing the tenacious support material can end up becoming a task for the technician.

Digital light processing (DLP) – a projector light source cures the liquid resin, layer after layer. The object is built on an incrementally elevating platform, which results in good accuracy and smooth surfaces, at a lower cost of technology. As always, the resin is messy, and can cause skin irritation by contact.

Selective laser sintering (SLS) – this technology can be used for both resin polymers which include nylon, elastomers and composites and metal alloys which may be titanium, titanium alloys, cobalt chromium alloys or even stainless steel. Here, the object is built layer by layer, in a powder bed. The metallic manufacturing processes have been described as selective laser melting (SLM) or direct metal laser sintering (DMLS).

Electron Beam Melting (EBM) – Powder is sintered layer by layer on a descending build platform in a heated build chamber, by scanning electron beam. This technology performs in high speed, in a high temperature setting, thereby eliminating the need for any heat treatment later. However, it poses serious health hazards because of the dust, and also carries an explosive risk.

Fused Deposition Modelling (FDM) – Thermoplastic material extruded onto a build platform, through a nozzle. But this technology results in variable mechanical strength, due to high porosity, which in turn leads to low accuracy.

Clinical Aspects:

All most all spheres of dentistry have started reaping the benefits of 3D printing through extensive usage. The factor of precision and intricacy has paved an undeniable path for additive manufacturing in the field. The interest of research and development has led to an increase in the publications related to this topic multi-fold over the past decade. Umpteen number of cases are being satisfactorily restored and rehabilitated with the use of the technology rendering the procedure less tedious and cumbersome for the clinician, patient and even the technician in most of the scenarios.

The main focus of 3D printing has mostly fallen on major specialities such as Prosthodontics, Implantology, Oral Surgery, Orthodontics, Periodontics and Endodontics in all the three domains of experimental, educational and clinical aspects. [4,5]

Prosthodontics:

In Prosthodontics, the impact of 3D printing has been enormous due to the need for an array of treatment modalities available within the field. There has been evidence indicating the feasibility of restoring lost complete or partial dentitions using the 3D printing of removable partial and complete denture. Selective laser melting has been employed to print crowns and copings, cast partial denture frameworks and retentive bars. The technology has made it less tasking to fabricate silicone based maxillofacial prosthesis with extensive defects with ease and literature shows positive results with regards to physical and mechanical properties of silicone and resin prosthesis that can be printed.

Bioprinting of defect models and also prosthetic graft substitutes which are to be placed within the tissues such as cranial defects and oro-facial defects have also been used. The Photojet printing of resins for splints to treat and rehabilitate Temporo-mandibular disorder patients have also been an area of interest over the near past. Rapid prototyping of casts and models have also been carried out. Exploration of printing ceramics and to equalise their properties to milled ceramics are also underway. [5,6,7]

Oral Surgery:

In Oral surgery, main lime light of 3D printing is attributed to the preparation of models using Computed Tomography data which are beneficial for diagnosis, pre surgical planning, template for fabrication of surgical stents and guides and post-surgical splints. Scaffolds for bone grafting using biocompatible tissue material such as hydroxyapatite, Beta calcium phosphate and polylactic acid have become a keen research interest. Infusion of osteo inductive materials is also being considered. [8,9]

Orthodontics:

3D printing in Orthodontics has refurbished the diagnosis, planning and execution of the treatment through 3D facial scans, printing of accurate models, and even appliances and brackets. Bioprinting of the complex oral structures to assess their capacity of force tolerance has been a field of interest lately. Aligners are removable regulatory splints used to reposition mal-aligned dentition, which can be anticipatorily planned using a computerised software and the models can be printed sequentially while the aligner can be SLA printed. 3D printed brackets are custom fabricated targeting the contact point between the wire and teeth which can preclude demineralisation and root resorption and also could achieve the preferred treatment outcome.[8,9]

Periodontics:

Regenerative periodontics have shone bright over the past decade due to the use of 3D printed guides for aesthetic gingival correction. The use of additive biomanufacturing applying 3D printed scaffolds to support tissue regeneration in a defect is popularly used in periodontics. 3D printing also finds its application in guided tissue regeneration and tissue engineering wherein scaffolds can be printed. [8,9]

Endodontics:

The principle of 3D printing in Endodontics has been applied to deliver stem cells, pulp scaffolds, injectable calcium phosphates and growth factors aiming at regenerative endodontics. 3D printing of guides for guided apicoectomy and endodontic access cavity preparation for challenging cases and study models have found space in current procedures. [10]

3D Printing – a Multidisciplinary Boon:

The interdisciplinary aspect of the technology has been well attributed but seldom discussed. The possibility of rehabilitating an implant supported prosthesis stands as an epitome between the surgical and prosthodontic aspect of the field where the prosthetic rehabilitation using a DMLS printed bar retained prosthesis with a printed framework can be utilised in a case of maxillofacial defects where a custom fabricated implant can be placed while the surgery can be planned using a 3D printed model while an SLA printed scaffold or stent can be placed for healing.

The 3D models and its feasibility for mock surgery planning has been extensively exploited for orthodontic and orthognathic correction of cases where the intra oral and facial scans can be used to prepare a mock surgery and verify the end result where the cast can be procured to plan for custom fabricated brackets and the stabilisation splints can be given to bring about holistic betterment in the treatment protocol.

Guided surgery has attained state of the art progress in implantology where a prosthetic planning can be carried out pre-operatively which can be scanned and super-imposed to be used for implant placement guides. These guides range from pilot drilling guides to sequential drilling guides. The prosthetic components and abutments can be later Additively manufactured for the ease of restoration. 3D printing of Poly methyl methacrylate temporaries has revamped the provisionalisation in implant dentistry as well.

Direct Metal Laser Sintering of intra coronal and extra coronal restorations along with endodontic access cavity guides have bridged the restorative procedures rendering the procedure quick and responsive.

CONCLUSION

The elaborate plethora of treatment modalities of additive manufacturing ultimately aims at bringing about regeneration, restoration and rehabilitation at every minute level in the field of medicine and dentistry.

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