IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 5 Ser.7 (May. 2023), PP 31-36
www.iosrjournals.org

3d Printing : A New Dawn In Era Of Periodontics

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Abstract:
Background: *Use of technology has made life easier for dentists. Three- dimensional printing (3D) is gaining much popularity in dentistry these days. 3D printing is one such emerging technology for regenerative medicine that enables the fabrication of living tissues using the living cells by the printing process. In addition to that , they are now being used in manufacturing various materials such as sports goods, fashion items such as jewelry and necklaces to aerospace components, tools for automobile industry, and medical implants also in dentistry for producing models, making scaffolds, etc. Regenerative procedures need placement of tissues that are biocompatible & bioresorbabale which promotes cell growth and proliferation in restoring defect. Such structures can be made from this 3D printing technology which uses several bioinks and various bioprinting methods such as autonomous self-assembly, extrusion-based, laser bioprinting etc., to print the tissues. Due to such applications, 3D printer can be used to fabricate scaffolds & biomembranes which can aid in regenerative procedures. This particular review deals with 3D printers, its applications & various materials that are used in periodontal regeneration.*

Keywords: *3D printing, bioinks, scaffolds, periodontal regeneration*

Date of Submission: 11-05-2023 Date of Acceptance: 21-05-2023

I. Introduction

Technology has now steadily gained its way into dentistry[1]. Proper treatment planning has now become easier than it was before with use of Digital OPG (Orthopantomogram), RVG (Radiovisuography), CBCT (cone beam computed tomography), digital impression machines, and in office CAD-CAM milling machines[2].

One such latest technology is 3D Printing. It is considered as cutting edge technology which has the power to change the way products are manufactured and can be used in field of regeneration that facilitates the fabrication of multiscale, biomimetic, multi-cellular tissues with highly complex tissue microenvironment, intricate cytoarchitecture, structure-function hierarchy, and tissue-specific compositional and mechanical heterogenicity. 3D printing is generally used to denote a manufacturing approach that builds objects one layer at a time, adding multiple layers to form an object. This is also referred to as rapid prototyping[1]. The 3D printer uses a powder or liquid resin that is slowly built from an image on a layer-by-layer basis. Thousands of cross sections of each product determine exactly how each layer is to be constructed with use of 3D CAD software.

This technology primarily uses raw materials like plastics, resins, super alloys, such as nickel-based chromium and cobalt chromium; stainless steel; titanium; polymers; and ceramics composite materials and polycaprolactone. This review articles discusses about 3D printing and also sheds some light on materials & various technologies used most often in 3D printed scaffolds for periodontal regeneration.

II. Materials Used in 3D Printers

There are several materials that are used in 3D printing. Commonly used materials for periodontal regeneration are :

Hydrogels & Polymers : Most commonly used materials for 3D printing in biomedical applications are Synthetic Polymers[3]. Polymer hydrogels are ideal candidates for the development of printable materials for 3D printing. Three-dimensional printing of polymers and hydrogels generally depends on the use of materials with controlled viscosity, which then decides the range of printability of the ink. Polymer inks require to be viscous enough to allow for structural support of subsequent printed layers while being fluid enough to prevent nozzle clogging[4]. Prepolymerized cell-laden methacrylated gelatin hydrogels are now been used successfully for bioprinting applications[5].

Ceramics : Ceramic scaffolds are usually composed of calcium and phosphate mineral phases, such as hydroxyapatite8 or ß-tricalcium phosphate[1]. Although ceramic scaffolds are not compatible with cell encapsulation for bioprinting, the ability of these scaffolds to upregulate osteogenesis due to the formation of a bioactive ion-rich cellular microenvironment, as well as their ability to mechanically provide space maintenance, makes these materials interesting alternatives for 3D scaffold fabrication[4].

Composite materials : Printable composites, which are usually in the form of copolymers, polymer-polymer mixtures, or polymer-ceramic mixtures, allow for the combination of several advantageous properties of their respective constituents, thus forming interesting candidates for bioinks used in craniofacial regeneration[4]. In addition to the advantages of polymer composite hydrogels, such as interpenetrating polymer networks (IPNs) or hybrid hydrogels , the incorporation of synthetic fillers to printable materials has also received extensive attention in the current literature. The combination of hydrogels with filler materials and/or natural peptides with morphogenetic capacity is certainly an area with great potential for future application in 3D printing for regenerative craniofacial repair[4].

Polycaprolactone : Polycaprolactone (PCL) was one of the earliest polymers synthesized by the Carothers group in the early 1930s[3]. Polycaprolactone (PCL) is a hydrolytically biodegradable polyester approved by the FDA for some clinical indications and is easily manufactured into a variety of shapes and porosities with variable mechanical properties and has been the material of choice in multi-phasic scaffolds for regeneration of periodontia[6]. Scaffolds for tissue engineering have become a large focus of research attention and can be fabricated in a wide variety of ways and a biomaterial which lends itself very well to scaffold fabrication is PCL[3].

III. Different Technologies of 3D Printers

There are certain technologies which are taken into account for 3D Printing and are mentioned as follows :

- Stereolithography (SLA)
- Direct Light Processing (DLP)
- Fused Deposition Modeling (FDM)
- Inkjet Powder Printing
- Selective Laser Sintering (SLS)/Direct Metal Laser Sintering (DMLS)

Stereolithography (SLA) :

Stereolithography (SLA) is the regarded as the first rapid prototyping process and was developed in the late 1980s[7]. Printers using this method employ a perforated platform located beneath a container of a liquid UV-curable polymer (photopolymer), together with a UV laser[1]. Fabrication of anatomical models for pre-surgical planning, and indirect fabrication of medical devices by using the SLA patterns for molds (e.g. filling a SLA structure to use as a negative mold) are some of its medical applications. The advantages of SLA consists of ability to create complex shapes with internal architecture, ease of removal of unpolymerized resin, and extremely high feature resolution (~1.2 um) . The main disadvantage of SLA is the scarcity of biocompatible resins with proper SLA processing properties[7].(Figure 1)

Figure 1 : Stereolithography (SLA) 3D Printer
Source : Formlabs[8]

Direct Light Processing (DLP) :

This is other optical technique which uses a light projector operating at UV wavelengths to project voxel (volumetric pixel) data into a photopolymer, which causes the resin to cure and solidify. Each voxel dataset is made up of voxels with dimensions as small as 16 £ 16 £ 15mm in the X-, Y- and Z-directions[1].(Figure 2)

Figure 2 : Direct Light Processing (DLP) Printer
Source : Thomasnet[9]

Fused Deposition Modeling (FDM) :

It is the deposition of molten thermoplastic materials through two heated extrusion heads with a small orifice in a specific laydown pattern[7]. This technology was developed by Scott Crump in 1988[1]. It uses two materials: the modelling material, which constitutes the finished piece, and a gel-like support material which acts as the scaffolding. Material filaments are fed from the printer's material bays to the print head which moves in X- and Y-coordinates, depositing material to complete each layer before the base moves down the Z-axis and the next layer begins[10]. It melts thermoplastic polymer into a semi-liquid state and the head extrudes the material onto the build platform[7].(Figure 3)

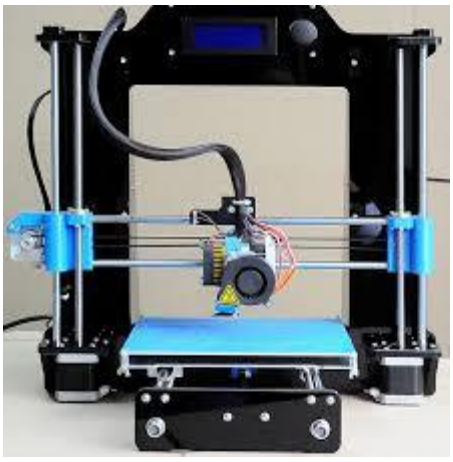

Figure 3 : Fused Deposition Modeling Printer
Source : Pixy.org[11]

Inkjet Powder Printing :

This process uses a glue or binder that is applied from an inkjet-style print head to bond successive powder layers together. The most frequently used powder is a gypsum based composite that needs to have its surface coated after printout if a robust object is required[10]. Commonly also called as 'binder jetters'. Some printers can jet both the binder and coloured inks from several separate printheads, allowing full-color 3D objects to be created with a resolution of up to 600 x 540 dpi[1].(Figure 4)

Figure 4 : Inkjet Powder Printer
Source : Businesswire.com[13]

Selective Laser Sintering (SLS)/Direct Metal Laser Sintering (DMLS) :

This technique was developed by the University of Texas in 1989. SLS is similar to 3DP in binding together powder particles in thin layers except a CO2 laser beam is used . The laser scans the surface of the powdered polymer particles in a specific 2D pattern to sinter by heating them above the glass transition temperature[7]. When SLS is used directly to produce metal objects, the process is called "direct metal laser sintering" (DMLS) or "laser melting"[10].(Figure 5)

Figure 5 : Selective Laser Sintering (SLS) Printer
Source : all3dp.com[14]

Periodontal Applications :

3D printing in periodontology include bio-resorbable scaffold for periodontal repair and regeneration, socket preservation, bone and sinus augmentations procedures, guided implant placement, peri-implant maintenance, and implant education[12]. All these applications are discussed below :

Three-dimensional printed bioresorbable scaffold for guided bone and tissue regeneration :

Development of 3D printed scaffolds is the recent advancement in the field of tissue engineering. Both hard (bone and cementum) and soft tissues (gingiva and PDL) components of the periodontium are competent mechanically with these multiphasic scaffolds. The main function of these scaffolds is to promote the formation of bone, PDL, cementum, and reestablishment of connection between them. Polycaprolactone is one such material that has been widely used as a scaffold material due to its successful outcomes in bony regeneration. The advantages of these scaffolds include 3D architecture that closely resemble extracellular matrix resulting in better regenerative capabilities[12].

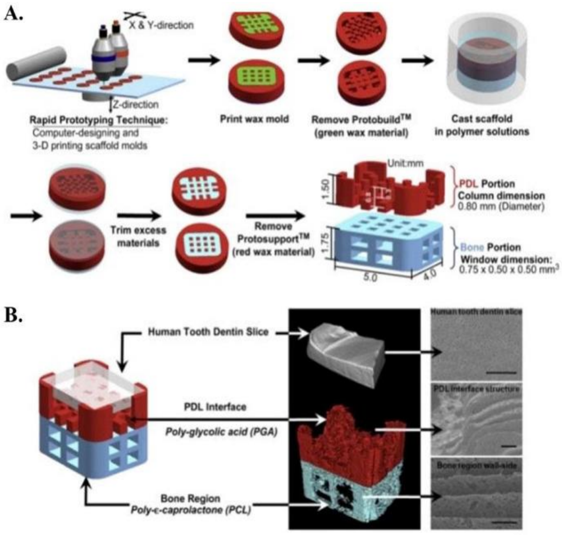

Figure 6 : Layered scaffolds in Periodontal Regeneration[15]

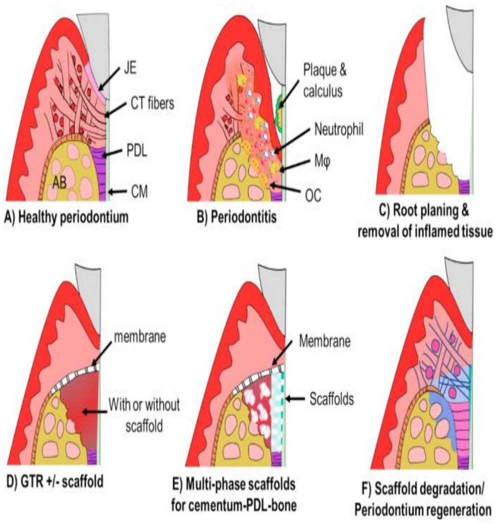

Figure 7 : Recent Advancements of scaffolds in integrated periodontal regeneration[15]

Three Dimensional Printing in Socket Preservation :

Recent advancement in technology has allowed the use of 3D-printed scaffold to preserve socket and maintain the dimension of the extraction socket. Park et al. reported a study on beagle dogs reported a predictable outcome with the use of 3D-printed polycaprolactone in socket preservation[12]. Clinical studies with long-term follow-up are missing and need consideration.

Three Dimensional Printing in Sinus & Bone Augmentation :

There are various methods that have described in literature for bone and sinus augmentation such as bone grafting, distraction osteogenesis, and guided bone regeneration. Role of 3D printing in bone and sinus augmentation and has shown positive outcomes in some literatures. The main adavantage of 3D printing is the ability to replicate the bony architecture and form macroporous internal structure of graft with minimal wastage of material because of the additive manufacturing technique. Some studies suggest the effective use of various materials for printing bone graft, including monolithic monetite (dicalcium phosphate anhydrous), biphasic calcium phosphate[12]. (Figure 8)

Three Dimensional Printing in Implant Placement :

Dental Professionals use implant placement procedure to replace missing teeth due to its predictable outcomes. Implant placement, if not done properly, can cause various complications such as poor esthetics, damage to anatomically important structures, infections, and implant failure. So to prevent such complications, Guided implant placement with fabrication of surgical guides by 3D printing can provide a positive outcome which will also help in accurate 3D placement of implant henceforth preventing any unwanted damage to anatomic structures and can reduce time.

Studies suggest that using 3D-surgical guide precise implant placement is possible in partially and completely edentulous patients even using flapless approach, reducing chairside surgical time, and patient comfort postsurgery and also allow simultaneous implant placement in complex cases[12]. (Figure 9)

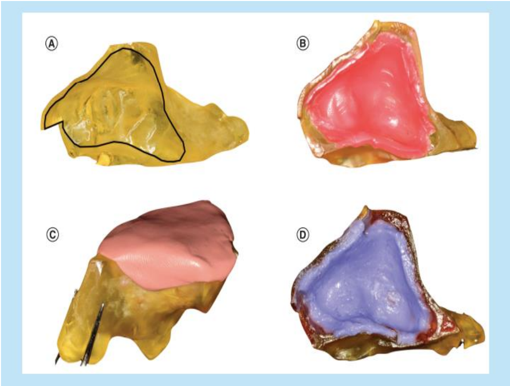

Figure 8 : Fabrication of Schneiderian membrane for sinus augmentation procedures[16]

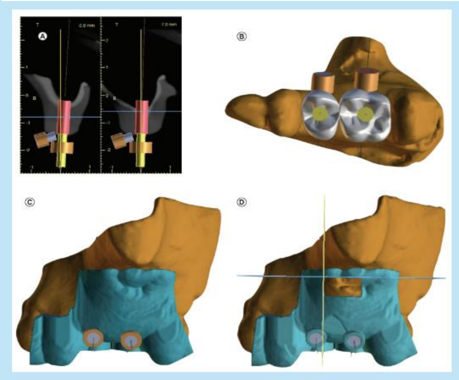

Figure 9 : Digital planning for guided implant placement using 3D printing[16]

IV. Conclusion :

3D printing in dentistry is a promising technological innovation for regenerative periodontology these days. 3D printing technology has been really efficient now, but the cost of the machines and materials, running and maintenance, and the need for a skilled operator have become a problem for easy access, availability, and use of this powerful technology, which has the ability to change the future of not only periodontology but also other specialities of dentistry. 3D-printed scaffolds show positive outcomes for bone and tissue regeneration as well as sinus and bone augmentation. Some studies have suggested that implant placement using 3D printing surgical template increases the accuracy, reduces deviation in position, incidence of complications, surgical time, postoperative pain, and swelling. 3D-printed models have a positive role as an education tool. However, few randomized controlled clinical trials are still to be conducted for future applications.

References :

[1]. Patel R, Sheth T, Shah S, Shah M. A new leap in periodontics: Three-dimensional (3D) printing. Journal of advanced oral research. 2017 May;8(1-2):1-7.

[2]. Chandrasekharan T, Prem M, Rajula B, Shankar R. 3D bioprinting: Print the future of periodontics.

[3]. Woodruff MA, Hutmacher DW. The return of a forgotten polymer—Polycaprolactone in the 21st century. Progress in polymer science. 2010 Oct 1;35(10):1217-56.

[4]. Obregon F, Vaquette C, Ivanovski S, Hutmacher DW, Bertassoni LE. Three-dimensional bioprinting for regenerative dentistry and craniofacial tissue engineering. Journal of dental research. 2015 Sep;94(9_suppl):143S-52S.

[5]. Bertassoni LE, Cardoso JC, Manoharan V, Cristino AL, Bhise NS, Araujo WA, Zorlutuna P, Vrana NE, Ghaemmaghami AM, Dokmeci MR, Khademhosseini A. Direct-write bioprinting of cell-laden methacrylated gelatin hydrogels. Biofabrication. 2014 Apr 3;6(2):024105.

[6]. Pilipchuk SP, Monje A, Jiao Y, Hao J, Kruger L, Flanagan CL, Hollister SJ, Giannobile WV. Integration of 3D printed and micropatterned polycaprolactone scaffolds for guidance of oriented collagenous tissue formation in vivo. Advanced healthcare materials. 2016 Mar;5(6):676-87.

[7]. Chia HN, Wu BM. Recent advances in 3D printing of biomaterials. Journal of biological engineering. 2015 Dec;9(1):1-4.

[8]. https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

[9]. https://www.thomasnet.com/articles/custom-manufacturing-fabricating/digital-light-processing-dlp-3d-printing/

[10]. Bogue R. 3D printing: the dawn of a new era in manufacturing?. Assembly Automation. 2013 Sep 23;33(4):307-11.

[11]. https://pixy.org/5549795/

[12]. Gul M, Arif A, Ghafoor R. Role of three-dimensional printing in periodontal regeneration and repair: Literature review. Journal of Indian Society of Periodontology. 2019 Nov;23(6):504.

[13]. https://www.businesswire.com/news/home/20200922005243/en/ExOne-Reveals-Advanced-InnoventPro-Metal-3D-Printer-Concept-Offering-All-New-Features-in-Binder-Jetting.

[14]. https://all3dp.com/1/best-sls-3d-printer-desktop-industrial/

[15]. Abedi N, Rajabi N, Kharaziha M, Nejatidanesh F, Tayebi L. Layered scaffolds in periodontal regeneration. Journal of Oral Biology and Craniofacial Research. 2022 Sep 13.

[16]. Tuce RA, Arjoca S, Neagu M, Neagu A. The use of 3D-printed surgical guides and models for sinus lift surgery planning and education. Journal of 3D printing in medicine. 2019 Aug;3(3):145-55.