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ORIGINAL RESEARCH PAPER

Periodontology

3-D PRINTING TECHNOLOGY IN PERIODONTOLOGY-A REVIEW

KEY WORDS: 3d Printing, Dentistry, Periodontology

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ABSTRACT

The field of dentistry is constantly evolving to best suit the patient needs and integrate dentistry with technology. Latest technological innovations like three dimensional (3D) printing and cone beam computed tomography (CBCT) have made treatment planning and its execution a whole lot easier and has thus been gaining much popularity. The process of 3D printing entails the creation of an object from the raw material, layer by layer. 3D printing has diverse applicability in the various specialities of dentistry such as endodontics, orthodontics, periodontology, maxillofacial surgery, prosthodontics and restorative dentistry. This article briefly describes 3D printing technology and its applications in periodontology.

INTRODUCTION

3D printing has been hailed as a revolution as it has caused a technological advancement in the way objects have been manufactured. The term 3D printing ;also referred to as additive manufacturing/ rapid prototyping is generally used to describe a manufacturing approach that builds objects one layer at a time, adding multiple layers to form an object.[1]

A virtual image of the object is sliced into several layers and are fused together by means of a binding agent or through sintering.[2]

Conventionally, converting a raw material to a fully finished and usable product comprises several steps, which can be eliminated by using this process. Thus, 3 D printing has found its application in various fields such as automotive, aerospace, printed electronics, and the medical sector.[3]

Dentistry is one avenue in medicine that has greatly benefitted from the use of 3D printing.[3]

The applications of 3d printing in dentistry includes maxillofacial implants, dentures, and other prosthetic aids as well as surgical training and planning with the use of anatomical models.[3] In dentistry we also have ready access to volumetric data in the form of CT scan data, CBCT data, and intraoral data.[1]

3D printing has found its applications in all the fields of dentistry such as endodontics, orthodontics, periodontology, maxillofacial surgery, prosthodontics and restorative dentistry.

The advantages of the 3D printing include thorough preoperative planning, improved accuracy of fit of prosthesis, and reduction of procedure time. The major demerit is the time and cost spent which renders the justified use of this technology in complex cases only.[4]

3D PRINTING TECHNOLOGY

What is 3D printing?

Three-dimensional printing is a method that is fundamentally derived from additive manufacturing technology.[5] In principle, objects are fabricated by adding materials layer by layer, hence rendering a 3D volumetric structure.[6]

The 3D printer uses a powder or liquid resin that is slowly built from an image on a layer-by-layer basis. The printed structures are designed using computer-aided design (CAD) software or from images obtained via CT, MRI or X-ray.[5]

Traditionally, 3D printing has been primarily used to fabricate scaffolds constituted of synthetic inks such as polymer hydrogels, sintered calcium and phosphate ceramics, inert metals that are then seeded with living cells and tested in vivo after implantation.[5] Visualization of treatment outcomes makes it a promising tool for clinical use.7

3D PRINTERS

The most widely applied 3D printers used include-

1. Fused deposition modelling (FDM)
2. Selective laser sintering (SLS)
3. Stereo lithography (SLA)
4. Inkjet Powder Printing
5. Direct Light Processing (DLP)

- **Fused deposition modelling** printers invented by Scott Crump in 1988, are the most commonly used 3D printers in a medical or dental set-up owing to its wide availability, reliable printing quality, ease of installation and use as well as affordability. The technology is based on material extrusion in which a semiliquid material is deposited by a computer-controlled printhead.[8]

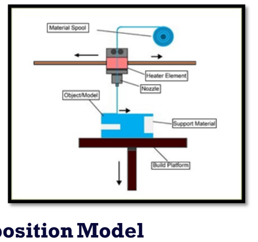

Fig 1: Fused Deposition Model

- **Selective Laser Sintering** technology uses heat rather than a binder to bond powdered materials together and produces objects by laying down a fine layer of powder and using a laser selectively to fuse some of its particles together. When it is used directly to produce metal objects, the process is called "direct metal laser sintering".[9]

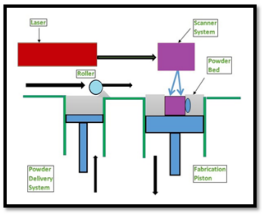

Fig 2: Selective Laser Sintering

- **Stereo Lithography Technique** is one of the first techniques to be commercially available. This technology employs a perforated platform located beneath a container of a liquid UV-curable polymer together with a UV laser.[9]

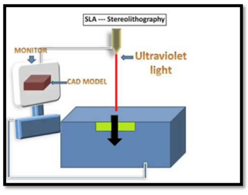

Fig 3 : Stereolithography technique

- **Inkjet Powder printing;** also known as binder-jetting printers involves selectively bonding successive layers of a powdered material together. Glue or binder is applied to bond successive powder layers together.[9] It has been extensively used to print living cells and tissue engineering constructs.[10]

The printer with highest resolution that is commercially available is the **Polyjet printer**, which is a combination of inkjet technology and photopolymers. Which have the advantages of having a wide range of printing materials, quick printing process, and replication of complex geometries.[11] It finds major application in surgical planning on patient-specific 3D models with complex anatomies, surgical stents and guides, phantom models for surgeries, and scaffolds for tissue engineering.[12,13,14]

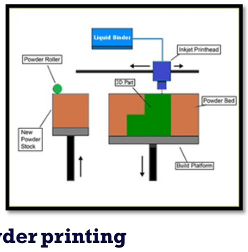

Fig 4 : Inkjet powder printing

- **Direct Light Processing** is an optical technique, which uses a light projector operating at UV wavelengths to project volumetric pixel (voxel) data into a photopolymer. This causes the resin to cure and solidify.[14]

Fig 5 : Direct Light Processing

MATERIALS USED IN 3D PRINTERS

The material to be used depends on the object to be printed. Many different materials can be used for 3D printing such as thermoplastic polymers like polylactic, acrylonitrile butadiene styrene, polycarbonate , polyether ether ketone, variety of resins for photo polymerization, ceramic filled resins, powders such as alumide, polyamide, glass-particle filled polyamide, rubber-like polyurethane cell-loaded gels and inks based on collagen, photopolymer resins, agarose, alginate, hyaluronan, chitosan and a variety of photopolymers .

MATERIALS MOST OFTEN USED FOR PERIODONTAL APPLICATIONS ARE

1. Polymers and hydrogels
2. Ceramics
3. Composite materials and
4. Polycaprolactone

- **Polymers and Hydrogels** are ideal printable materials for tissue engineering.[5] Synthetic polymers are the class of materials most commonly used for 3D printing in biomedical applications.[15] Since high temperature is usually involved during the printing process, the direct incorporation of cells or growth factors in the polymer mixture is generally avoided.[16] Hydrogels present high biocompatibility and remarkable tunability of rheolo gical, mechanical, chemical, and biological properties.[5] More recently, prepolymerized cell-laden methacrylated gelatine hydrogels also have been used successfully for bio printing applications.[17]
- **Ceramic scaffolds** are usually composed of calcium and phosphate mineral phases, such as hydroxyapatite or beta-tricalcium phosphate.[18,19] In ceramic scaffolds, cells quickly populate the scaffold surface establishing close cell-cell interactions and promoting cell proliferation and differentiation. Ceramics also have much lower rates of degradation which allows for prolonged guided tissue remodelling and structural support.[5]
- **Composite materials**, which are printable, are usually in the form of copolymers, polymer–polymer mixtures, or polymer–ceramic mixtures and form interesting candidates for bio inks used in craniofacial regeneration.[20] Composite has the ability to expose highly hydrated 3D microenvironments and generally present very low stiffness compared with the majority of load-bearing tissues of the craniofacial region. Therefore, printing of scaffolds for reconstruction of tissues subjected to higher mechanical loads, such as the periodontal complex, usually requires the use of ceramic materials or composite scaffolds.[21]
- **Polycaprolactone (PCL)** is a biodegradable polyester easily manufactured into a variety of shapes and porosities with variable mechanical properties and has been the material of choice in multiphasic scaffolds for regeneration of periodontium.[22]

PERIODONTAL APPLICATIONS OF 3D PRINTING

3D printing has applications in periodontology with a focus on periodontal regeneration in research, 3D-printed guides for aesthetic gingival correction and 3D printed models for surgical planning and education purposes.

3D printing has gained popularity in aesthetic gingival surgeries.[23] Patient specific surgical guides are printed and used for gingivectomy procedures and smile designing which are known for their accuracy, customization, and precision.[7]

Research is still going on the use of 3D printing technology in regenerative periodontology. It has recently been applied to develop hierarchical scaffolds, mimicking the properties and architecture of the periodontium, which consists of both soft and hard tissues which include gingiva , periodontal ligament, bone and cementum .[5] These scaffolds are referred to as multiphasic constructs, as they possess various compartments summing up the basic structure of the periodontium.[24] Fused deposition modelling is an example of extrusion-based printing technique, which has potential application in periodontal regeneration. Various 3D printing techniques find application in tissue regeneration based on the requirements of the defect area. A CT scan of the defect in a patient serves as template for the creation of 3D objects. Electrospinning is a broadly used micro-nano fibre fabrication technique is another scaffold fabrication method explored for periodontal applications.[25]

Rasperini et al. fabricated the first reported personalized additively manufactured bio scaffold for periodontal osseous defect regeneration in humans.[26]

3D printing can also be used in guided tissue regeneration. The principle of controlled tissue regeneration is to prevent the ingrowth of rapidly regenerating tissues such as the oral epithelium into the defect and at the same time provide room to the slow-growing bone tissue for regeneration.[27]

Surgical implant guides can be fabricated with the help of 3D printing which will help in accurate 3D placement of implant thus saving time and preventing unwanted damage to anatomic structures.[28]

Recently, Ren et al had done a study using flow-through dissolution chambers constructed using 3D printing for local drug delivery. It was found out that it provided flexibility of the dissolution chamber design for drug delivery to the periodontal pocket.[29]

Dental students are trained either on models or directly on patients for periodontal examination and procedures, which has led to many difficulties for both the patient and students during the procedure.[30] Hence, it would be a good approach to print 3D models simulating the periodontal tissues to develop the correct proprioception and skill before operating on the patient. Patients can also be educated about the procedure on 3D printed models.

CONCLUSION

3D printing has the capacity to revolutionize dentistry.3D bio printing enables the fabrication of biostructures closer to natural dental tissues. Applications in dentistry are already diverse and it is a promising technological innovation for regenerative periodontology, which allows more predict ability in management of complex interdisciplinary clinical scenarios. Development of advanced biomaterials that influence the biological environment in a controllable manner leads to patient- specific treatment options with predictable clinical outcomes. Nevertheless, the application of 3D printing in dentistry remains a brand new field, in which various challenges are present in the potential of this technology. Although 3D printers have become more affordable and popular commercially, there is still a long way to go before this has a widespread use in different specialties of dentistry.

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