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EC DENTAL SCIENCE
Mini Review

# Fused Deposition Modeling and Stereolithography 3D Bioprinting in Dental Science

**Danial Khorsandi[1,2]*, Amir Fahimipour[3], Sepehr Sadeghpour Saber[4], Amir Ahmad[4] and Andrea Amoretti De Stephanis[4]**

[1]*University of Barcelona, Barcelona, Spain*

[2]*Center for Minimally Invasive Therapeutics (C-MIT), University of California-Los Angeles, Los Angeles, CA, USA*

[3]*Shahid Beheshti University of Medical Sciences and Health Services, Tehran, Iran*

[4]*International University of Catalunya, Faculty of Dentistry, Sant Cugat, Barcelona, Spain*

***Corresponding Author**: Danial Khorsandi, University of Barcelona, Barcelona, Spain and Center for Minimally Invasive Therapeutics (C-MIT), University of California-Los Angeles, Los Angeles, CA, USA.

**Received:** December 13, 2018; **Published:** December 27, 2018

**DOI:** 10.31080/ecde.2018.18.00897

## Abstract

3D printing has been admired as a cutting-edge technology, which will change manufacturing [1]. Recent advances in bioprinting technologies have enabled rapid manufacturing of medical models in many fields and areas. Recently in the field of dentistry, fused deposition modeling and Stereolithography 3D bioprinting techniques have been using in dental applications such as implants, the production of physical models for prosthodontics, orthodontics, and surgery [2,3]. This paper reviews the usage of fused deposition modeling and stereolithography 3D printing technologies and their various applications in dentistry and in maxillofacial surgery. 3D printing is transforming digital dentistry by extensively penetrating opportunities in diagnosis, treatment and education. The accelerated research in this industry and optimism would open more doors to help revolutionize digital dentistry.

***Keywords:*** *Fused Deposition Modeling (FDM); Stereolithography (SLA); 3D Printing; Dentistry, Dental Devices*

## Abbreviations

FDM: Fused Deposition Modeling; SLA: Stereolithography Apparatus; UV: Ultraviolet; ABS: Acrylonitrile Butyro Styrene; SLS: Selective Laser Sintering

## Introduction

3D printing in general, fused deposition modeling (FDM) and Stereolithography (SLA) in particular, will be a significant aid for improvement of local clinics. 3D printers aids the medical science by printing cells, organs and fabricating tissues. The purpose of the 3D printers are to assist medical science with deficiency in sources of organs, once the researches are successfully completed [4].

Dental technicians mainly rely on their individual techniques in performing bridges, inlays, onlays, veneers and frameworks, which is not practically following with sufficient accuracy and extremely time-consuming, and material requirement in traditionally performed treatments may be followed with certain complications in durability and esthetic [5]. Access of dental companies to 3D printers are undoubtedly extending whether in local practices or laboratories. 3D printers generate valuable benefits, with capacity to apply new manufactured and higher precise materials with improved productivity and efficiency [6].

For instance, in the FDM method, the nozzle is heated to melt the thermoplastic and the viscous plastics can be deposited by an extrusion head. Although FDM is a flexible printing method with capacity of operating variety of high viscous material, its productivity will be limited due low product resolution, lack of surface smoothness and prolonged working time [5,7].

| | Fused deposition modeling (FDM) | Stereolitography (SLA) |
|---|---|---|
| **Material** | • Polycarbonate,<br>• Acrylonitrile<br>• Butadiene styrene,<br>• Polyphenylsulfone<br>• Calcium Phosphate based ceramic<br>• Nylon | • Resin |
| **Advantages** | • No chemical post processing,<br>• Cost-effective | • Product resolution,<br>• Short working time<br>• The transparency of the model and the recent development of color resins allow distinct visualization of anatomical structures<br>• Almost no deformation until sudden fracture |
| **Disadvantages** | • Low resolution, lack of surface smoothness, long working time, limited shape complexity<br>• Gradual deformation | • Over curing,<br>• Lack of surface smoothness,<br>• Limited mechanical strength,<br>• Irritant<br>• Mechanical strength is limited by the viscosity of the resin used |
| **Layer thickness** | 0.5 to 0.127 mm | 0.05 to 0.015 mm |
| **Applications in Dentistry** | • Custom impressions<br>• Custom bite registrations<br>• Wax Set-Up for Try-In | • Fabrication of surgical drilling patterns in dental implant insertion<br>• 3D printing of temporary and definitive crowns<br>• 3D printing of temporary bridges<br>• 3D printing of temporary restorations surgical guides<br>• Splints<br>• 3D printing of dental replica models |
| **References** | [4,8,9] | [6,10-17] |

***Table 1:*** *Fused deposition modeling and Stereolithography 3D printing differences in dental application.*

## Fused deposition modelling

Fused deposition modelling developed by Schott Crump, uses a nozzle with a set temperature in which a melted thermoplastic material is extruded and hardens almost immediately due to a colder temperature of the air. A processor allows the movement of the nozzle head, and therefore, deposit a thin layer of material on a supplementary platform. FDM uses polymers such as Acrylonitrile Butyro Styrene (ABS), polycarbonates and polysulfones. An alternative extruder is needed in order to manufacture complex products [8,11].

The characteristics of the thermoplastic material used are crucial for the accuracy of the printer, such as the flow of the material. This process is used by common 3D printers, and allows the printing of simple, basic and rudimentary models such as flat bones (Figure 1A) [12-17].

## Stereolithography

History of Stereolithography (SLA) dates back to 1986 and was introduced by Charles Hull [18]. Principle of making solid objects involves successive printing of thin layers of Ultraviolet (UV) curable photopolymer layer by layer. The mechanical strength of the materials used by SLA makes it favorable for the production of prosthodontic obturators, surgical and burn stens and the replication of high variety prosthesis [19]. The curing time and the thickness of the layer polymerized is affected by the dynamics involved in the entire procedure.

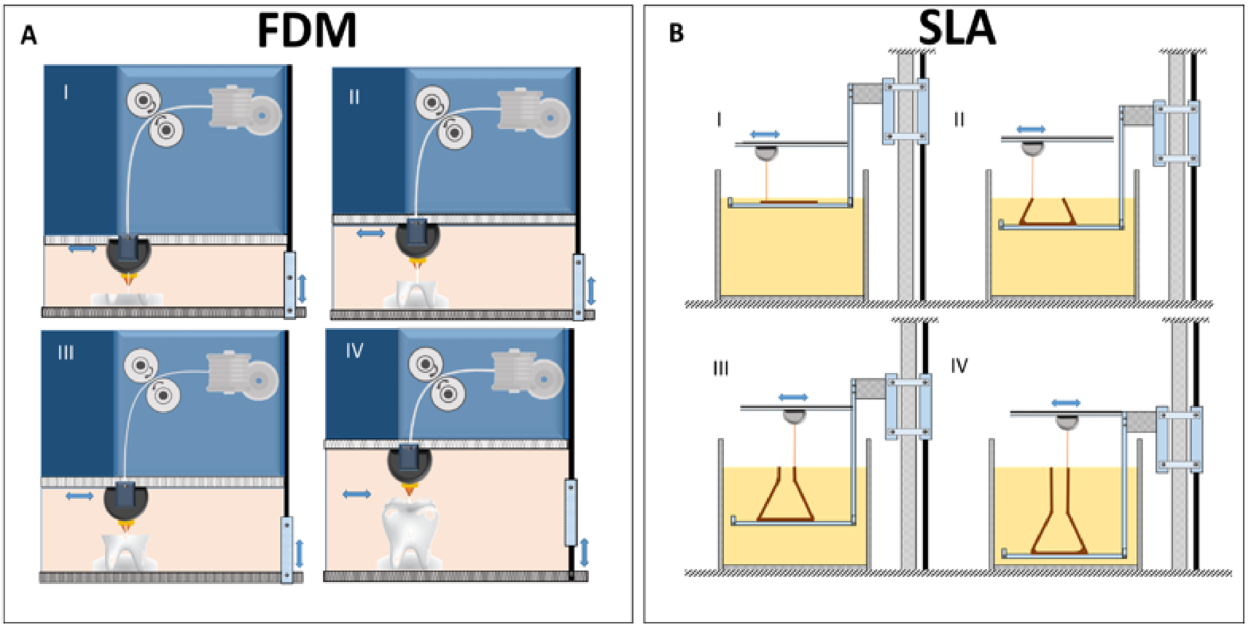


*__Figure 1:__ Fused deposition modeling and Stereolithography methods- (A) Fused deposition modeling .The nozzle is heated to melt the thermoplastic and the viscous plastics can be deposited by an extrusion head (I-IV). (B) Stereolithography a computer-controlled laser to draw the first layer onto the surface of a liquid polymer, which hardens where struck by the laser.*

The kinetics can be controlled by power of the light source, scanning speed, chemical structure, amount of monomers and photo initiators. In order to obtain higher control over the depth of the polymerization UV-absorbers can be mixed with the resins [20]. One of the major disadvantages of SLA is the lack of biocompatibility of the resins when correctly processed. Additional challenges are the use of photo initiators and radicals which may be cytotoxic (with long processing times), entrapment of unreacted monomer and residual photo initiator, and inability to create compositional gradient s along horizontal planes [21] (Figure 1B).

SLA has been extensively applied in tissue engineering [22,23], tissue scaffolding [24,25], fabrication of implantable devices [26] and more recently in the dentistry field. The process is set up within a reservoir in which the liquid polymers will spread out over a platform. This machine then uses a computer-controlled laser to draw the first layer onto the surface of a liquid polymer, which hardens where struck by the laser. The model is then lowered and the next layer is then drawn directly on top of the previous one. This is repeated until the model is finished. This is how eventually layer by layer the desired device is created in liquid with the support of the laser, uniting the layers for the duration of the process [27].

## Discussion

Currently, the leading objective for using 3D printed models in dentistry is fabrication of surgical drilling patterns in dental implant insertion [15-17]. Furthermore, the transparency of the model and the recent development of color materials, allow distinct visualization of anatomical structures. The SLA process includes scanning speed, laser power, exposure time, the selection of resin and the amount of polymer [28]. SLA offers a great efficiency, high level of accuracy. An object can be produced at a resolution down to 0.05 mm, making SLA a superior technique compared to FDM [29].

FDM has been broadly used for commercially available rapid processed filaments collaborated with different types of polymeric materials such as polylactic acid (PLA). FDM enables the production of complex objects with high accuracy and with different substances via using multi-nozzle printing systems [30].

In addition, the surface of both FDM and SLA printed models are very rough, with layer patterns (See figure 2A). It can be inferred as the layer thickness of the two different technologies (FDM layer: 0.5 to 0.127 mm, SLA: 0.05 to 0.015 mm) [31,32].

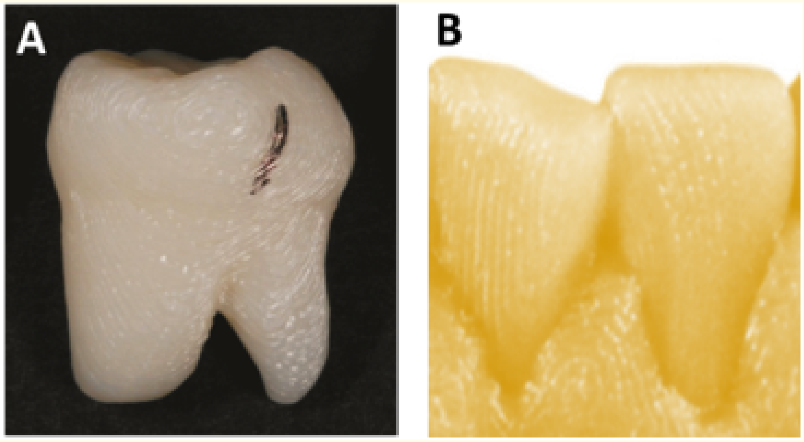


***Figure 2:*** *FDA and SLA printed replica tooth surface texture*
*(A) Replica tooth made by fused deposition modeling and (B) by Stereolithography.*

Therefore, in dentistry and replication the teeth by 3D printer, surface roughness which create bacterial retention *in vivo*. It needs to be polished to limit the bacterial retention.

## Concluding Remarks

FDM is a flexible printing method that can process a large range of high viscous material. It is limited to the temporary crowns and bridges fabrication due to its limited printing resolution, surface quality and time efficiency. Furthermore, FDM is relatively long process in comparison to SLA, which creates complex products with high resolution and a broad diversity of daily treatments.

Dependency of the material quality on products must be taken into account, as well as the surface roughness, which creates bacterial retention in vivo. In addition, the recent development of color resins allow distinct visualization of anatomical structures. In conclusion, due to its accessibility and the low cost of everyday materials, we believe that it is SLA will find its way to general clinics.

## Future Directions

Recent researches on application of FDM in electrospinning process has shown positive results in tissue engineering field that needs more researches in case of quality, efficiency and accessibility to dentists. To our knowledge, this is the first study conducted comparing FDM 3D bioprinting and SLA bioprinting in dentistry. Future studies should evaluate other 3D printing methods with different 3D printing machines and materials in dentistry and other medical applications.

## Acknowledgment

D.K. acknowledges the supports from the University of Barcelona, California NanoSystem institute at the UCLA and Procare Health Iberia.

## Conflict of Interest

The authors declare no conflict of interest.

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**Volume 18 Issue 1 January 2019**