International Journal of Health Technology and Innovation
An Official Journal of **Kalam Institute of Health Technology** | ISSN - **2583-8547**

REVIEW ARTICLE

Review of 3D Printing and Other Methodologies Used for Fabrication of Aesthetic Efficient, Passive, Biocompatible, Stable Dental Splints

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Received: 25th January, 2024; Revised: 15th February, 2024; Accepted: 07th March, 2024; Available Online: 05th April, 2024

ABSTRACT

Over the past decade, 3D printing has revolutionized dentistry, enabling a shift towards personalized, digitally driven treatment plans. This versatile technology allows for the on-demand creation of customized splints, including temporary prosthetics, implant guides, and aligners. Its efficiency, reproducibility, and affordability offer significant advantages over traditional methods, providing faster, more accurate results for patients. With the option of chairside printing or rapid outsourcing through dental labs, 3D printing empowers clinicians to deliver efficient, biocompatible, and stable splints with greater ease. The findings of this review will contribute to an understanding of the adoption of 3D printing technology in day-to-day dental practice.

Keywords: 3D Printing, Splints, Rapid prototyping, Stereolithography

International Journal of Health Technology and Innovation (2024)

How to cite this article: Sayed A, Joshi PD, Lobo W, Thakur K, Rathod Y, Baker DC. Review of 3D Printing and Other Methodologies Used for Fabrication of Aesthetic Efficient, Passive, Biocompatible, Stable Dental Splints. International Journal of Health Technology and Innovation. 2024;3(1):11-14.

Doi: 10.60142/ijhti.v3i01.03

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

3D printing, alternatively referred to as rapid prototyping (RP) or additive manufacturing (AM), utilizes computer-aided design and manufacturing (CAD/CAM) technologies or advanced imaging and scanning to build objects layer by layer.[1,2] In 1983, Charles Hull pioneered this technology with the first 3D-printed object using stereolithography. He later founded the company "3D Systems," which pioneered the commercial availability of the first 3D printer, known as the "SLA-250" in 1988.

There are two mechanisms for manufacturing dental splints, namely subtractive and additive.[3] Flowchart 1 depicts an overview of these methods two methods.

Conventional dentistry relies heavily on subtractive manufacturing, akin to milling, which cannot fully replicate complex structures due to limitations in capturing internal details. The rise of 3D printing and advancements in computed aided design (CAD) and imaging techniques like CBCT and MRI has revolutionized the field. Today, dentists can design and print dental and maxillofacial prostheses with remarkable accuracy, restoring and replacing lost structures with lifelike precision.[4] This review was undertaken to attain an overview of the available literature about the fabrication of splints using 3D printing to improve practitioners' understanding of such advancements.

Aims and Objectives

- To study the splint design and splint fabrication with 3D printing technology.
- To obtain biocompatible, cost-effective and user-friendly splints using 3D printing method.

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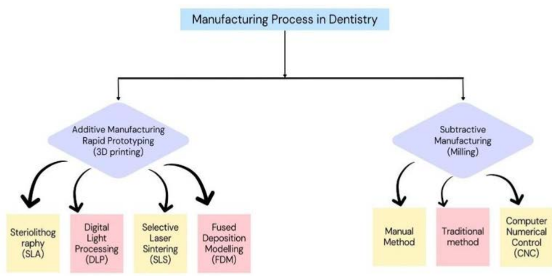

Flowchart 1: Schematic representation of various manufacturing processes in dentistry

Table 1: Advantages and disadvantages of most commonly used 3D printing technology

Type of 3D printing method	*Advantages*	*Disadvantages*
Stereolithography (SLA)	Highest resolution and accuracy	Complex processing
	Suitable for fine detail	Final product is weak
Digital light processing (DLP)	Simplest method	Lower resolution
	Offers smoothest finishes	Not suitable for surgical guide
Selective laser sintering (SLS)	Lower cost for patients	Not suitable for a large part
	Good mechanical properties	High maintenance
Fused deposition model (FDM)	Suitable for complex structure	Lower accuracy
	A wide range of materials can be used	Less finishing

- Comparison between 3D printing fabrication method and other established techniques.

Advantages of 3D Printing for the Fabrication of Occlusal Splints

There are several advantages for both the dentist as well as the patients namely:

- **Customization:** 3D printing enables the creation of patient-specific occlusal splints, ensuring a precise fit that addresses individual dental anatomy and occlusion.[5]
- **Accuracy:** The technology provides high precision in replicating digital models, resulting in splints that match the intended design without error and discrepancies.[6]
- **Time Efficiency:** 3D printing can produce occlusal splints faster than traditional methods, streamlining manufacturing and reducing patient appointments.[7]
- **Material Options:** A variety of materials compatible with 3D printing can be used for occlusal splints, allowing for flexibility in choosing properties such as durability and biocompatibility.[7,8]
- **Cost Effectiveness:** While initial setup cost for 3D printing can be significant, the ability to produce customized splints efficiently may contribute to cost savings over time, particularly in high-volume applications. [7,9]
- **Reduced Waste:** 3D printing generates less material waste than traditional manufacturing methods, aligning with sustainability goals.[7,10]

Figure 1: Composite splint lingual arch fabricated using conventional method

Figure 2: 3-D Printed models used for the preparation of occlusal splints

Stereolithography

The process involved in stereolithography (SLA) and digital light processing (DLP) technologies can be categorized into three distinct stages: light exposure, movement of the building platform, and replenishment of resin. Among the various 3D printing techniques used in dentistry, SLA stands out as one of the most extensively employed and oldest methods. In SLA printing, UV (Ultraviolet) lasers are utilized to solidify a liquid photopolymer resin into layers. This involves the gradual polymerization of the liquid resin as the laser comes into contact with it. Once each layer is cured, the build platform descends, allowing for the subsequent layers of resin to be solidified on top of one another. [11]

Fused Deposition Modeling

Fused deposition modeling (FDM) stands as one of the widely favored and cost-effective 3D printing technologies within the dental field. This method involves heating and melting filamentous thermoplastic material using a nozzle. Controlled by a computer, the movement of the nozzle and worktable occurs along different axis directions. The molten material is then extruded and gradually solidified, layer by layer, ultimately shaping the final product through the accumulation of these materials.[12]

Selective Laser Sintering

Selective laser sintering (SLS) and selective laser melting

Figure 3: Occlusal splint placed intraorally

(SLM), both classified under powder bed fusion processes, find application in the production of metal dental prostheses like fixed partial dentures, implant guides, and splints.[13] These manufacturing techniques involve the selective sintering of a thin layer of metal powder by a laser beam, guided by 3D data. The primary distinction between SLM and SLS lies in their treatment of the powdered material: SLM fully melts the powder, whereas, in SLS the powder is partially melted or sintered.[14]

Digital Light Processing

Within the realm of 3D printing, digital light processing (DLP) diverges from the use of a laser and employs a projector instead. Unlike SLA, where the light is constrained to a single spot, in DLP, the entire layer is crafted simultaneously once the light interacts with the resin. In this process, precise illumination patterns play a crucial role in achieving the intended shape for each layer. Three primary types of DLP solutions are available: network, endpoint, and cloud. [15]

This comprehensive approach and the associated technologies have the potential to be integrated into various stages of procedural workflows and can be effectively combined with traditional manufacturing methods to enhance overall efficiency and precision in production.[16]

Table 1 depicts in brief the advantages and disadvantages of the commonly used methods in 3D printing.

DISCUSSION

In earlier days, stainless steel wire and composite splints were the most commonly used splints in clinical practice (Figure 1). Conventional techniques used in the fabrication of splints involve methods such as the application of a sprinkled layer, thermoforming, and the lost wax technique. These splints have a number of drawbacks such as less mechanical retention, dependence on meticulous bonding protocol, plaque accumulation, and possible soft tissue laceration.[17-19] The conventional process for the fabrication and try in of splints is also very time-consuming and tedious.

3D printing occlusal splints provides many benefits over the traditional process and allows dentists to expedite treatment during each stage of the treatment process (Figure 2). A prominent attribute of digital splints lies in the smoothness of their contact surface (Figure 3). Unlike traditional manufacturing methods that might retain leftover material from the casting process, digitally crafted splints exhibit a flawlessly smooth surface. This absence of imperfections ensures a seamless experience, enabling the teeth to move freely across the splint's surface without any obstructions. Overall, the advent of 3D printing technology has proved to be superior, less invasive, and more accurate than conventional methods.[20]

CONCLUSION

3D printing in amalgamation with 3D imaging and CBCT technology have a huge impact on all aspects of medicine as well as dental practice, emerging as a trustworthy technology with a vast scope for betterment. Due consideration must be given to the cost of appliances, maintenance, and materials used.

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