Review Article

3D Printers in Orthodontics

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Abstract

The use of 3D printing in orthodontics has revolutionized treatment planning, appliance fabrication, and overall patient care. This technology enables the precise and efficient production of orthodontic devices such as clear aligners, customized brackets, study models, and surgical guides. By reducing material waste, minimizing production time, and enhancing customization, 3D printing offers significant advantages over traditional methods. In addition, its integration with digital scanning and computer-aided design allows for improved accuracy and patient-specific treatment solutions. As advancements in biocompatible materials and AI-driven automation continue to evolve, 3D printing is expected to further transform orthodontic practice. This article explores the applications, benefits, and future potential of 3D printing in orthodontics, highlighting its role in creating a more efficient, cost-effective, and patient-centered approach to treatment.

Keywords: 3D printers, Clear aligners, Customized bracket through 3D printers, Use in orthodontics.

Introduction and Objectives[1]

The world of manufacturing, prototyping, and even creative expression has been revolutionized by three-dimensional printers or 3D printers. According to a computer blueprint or design, using these printers, one can create tangible items by assembling layers of material. Traditional manufacturing methods entail cutting or molding material, whereas 3D printers create things layer by layer, providing unmatched customizability and flexibility.

In orthodontics, 3D printing usually entails using a digital scanner to create a 3D image of the patient's teeth and jaws. The patient's teeth and jaws are then digitally modeled using this image, allowing for further manipulation and modification to arrange the orthodontic therapy. A 3D printer is then used to turn the digital model into a physical model that may be utilized to make personalized orthodontic appliances.[1]

Key objectives include:[1,2]

- To explore the role of 3D printing technology in orthodontics and its impact on modern dental practices
- To highlight the various applications of 3D printing, including clear aligners, customized brackets, study models, and surgical guides
- To analyze the benefits of 3D printing, such as improved precision, reduced production time, and cost-effectiveness
- To explore the future of orthodontics with 3D printing technology.[1,2]

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Historical Context[1-3]

Hull introduced a stereolithographic 3D printer in the 1980s, laying the groundwork for 3D systems. Scott Crump created fused deposition modeling (FDM) a few years after the first 3D printer was released, and Prof. Ely Sachs created the inkjet printer system in 1995, which was capable of printing on metal and was the first to use the phrase "3D printing."[2]

Key contributions include:

- Stereolithography (SLA) invention: In 1983, Charles "Chuck" Hull, a co-founder of 3D Systems, developed a technique called SLA that employed a UV laser to layer-by-layer harden photopolymer materials to create 3D objects[2]
- FDM: Stratasys founder Scott Crump created FDM.[3]

Use of 3D Printers in Orthodontics[3-10]

Orthodontic models

In orthodontics, 3D printing technology may be utilized to create dental models for patients. The expanding use of digital dental models and intra- and extra-oral scanners has significantly

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reduced the necessity for taking plaster models and alginate impressions, which has allowed for the avoidance of the problems associated with traditional orthodontic models. Orthodontic diagnostics may benefit from the use of digital models. Digital models can be seen as an equal substitute for traditional plaster models due to their excellent validity, reliability, and repeatability when it comes to diagnostic measurements (Figure 1).[3]

Clear aligners

Aligners can be created straight from 3D printers or assembled using traditional methods using plaster and 3D-printed models. Geometric mistakes are frequent and widespread in the traditional method of vacuum-forming a thermoforming material because of the heat-forming process and model deterioration.[4]

The 3D-printed aligners have higher mechanical resistance and geometric accuracy (Figure 2).[4]

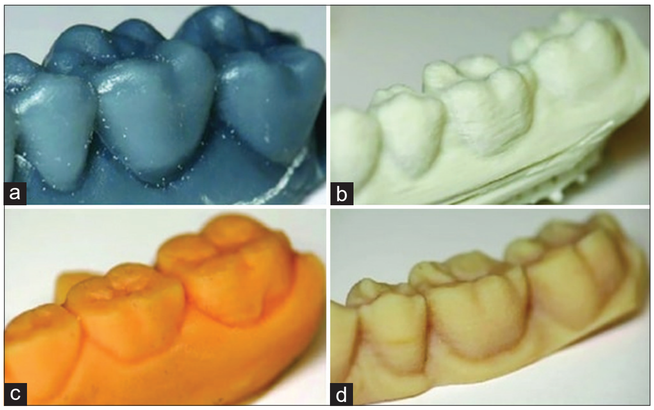

Figure 1: Depicts 3D printed models using (a) Stereolithography (b) Fused deposition modeling (c) Digital light processing (d) PPP printers

Figure 2: Depicts 3D printed clear aligner

Retainers

For the maintenance of occlusion, the retention phase following orthodontic treatment has long been crucial. Issues such as patients losing their retainers or the retainers deteriorating have been removed with the ability to quickly make replacements thanks to models created by 3D printers (Figure 3).[5]

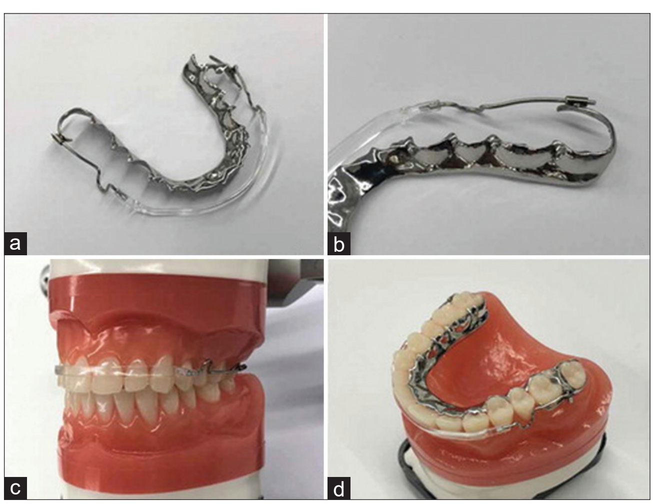

Figure 3: (a-d) Depicts a metal retainer manufactured by 3D printing

Removable appliance

In 1996, Sassani and Roberts used 3D printers to construct the first acrylic orthodontic devices that are semi-automated. According to their assertion, computerized systems have the capability to produce orthodontic devices, but it is necessary to pre-attach wires and screws to the model.

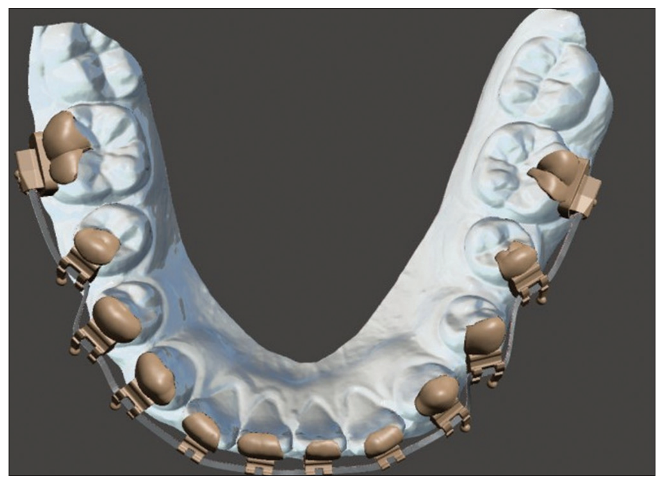

Figure 4: Depicts in-house 3D designing (computer-aided design) and printing of hybrid ceramic resin customized orthodontic brackets

Figure 5: Depicts 3D printed night guard

Figure 6: Depicts pre-surgical nasoalveolar molding with 3D printing for a patient with unilateral cleft lip, alveolus, and palate

To produce metal components such as Adams clasps and labial arcs, they conducted further research in 2015 utilizing the use of additive manufacturing technology and computer-aided design (CAD) software (version 12, Geomagic Freeform Modeling Plus; 3D Systems, Rock Hill, SC). Clasps and cables were manufactured using a secondary 3D printer and affixed to the foundational part of a printed Hawley appliance.[6]

Orthodontic auxiliaries

Nagib *et al*. used cone-beam computed tomography scans to manufacture a tailored chain for impacted canine teeth using a 3D printer. The attachment provided improved compliance and strong bonding, and it was simple to install during operations.

According to Ahamed *et al*., 3D printing technology can be used to create the lingual retainer, bite turbo, retraction hook, and aligner attachments. Following the scanning of dental arches or models to create digital models, auxiliaries were built using tools such as Netfabb and produced through FDM or SLA printing.

The capacity to create customized gadgets is the main benefit of 3D printers, according to the authors, who also stress how quickly these technologies will replace more traditional ones.[7]

Customized brackets

Using digital models created from silicone imprints, Wiechmann *et al*. calculated the bracket placements and created tooth-compatible bracket bases. They used indirect bonding to place personalized brackets, which were fabricated using rapid prototyping.

Digital light processing printing was used to print the personalized brackets, and post-processing was subsequently applied to enhance biocompatibility.

Duarte *et al*. employed a 3D printer to manufacture the transfer trays that 33 orthodontists used for indirect bonding. They next looked at the effect those trays had on the repeatability of bracket placements.

According to their statement, the digitally fabricated bracket and the bracket locations given by the transfer tray were mostly compatible. They stated that the positioning of brackets using this method was not significantly influenced by the orthodontist's years of clinical experience or previous expertise (Figure 4).[8]

Occlusal splint

The advancement of digital workflows and 3D printers has also had an impact on occlusal splints used in the treatment of temporomandibular joint problems. In comparison to traditional manufacturing, researchers are now able to create occlusal splints with adequate accuracy using 3D printers, which have reduced labor costs, patient waiting times, and laboratory processes.

Salmi *et al*. used SLA printing to manufacture an occlusal splint that they created using a digital model that they received from a scanned plaster model.

By overlaying the digital model on top of the splint, they were able to assess its wear and deformations. It was discovered that splints made using a 3D printer were just as successful as those made using more conventional techniques, and using them was advised.

In 2014, splint accuracy was examined through a comparison between rapid prototyping-produced splints and conventional surgical splints. It was demonstrated that although the quick surgical splints had a large error range, their accuracy was tolerable (Figure 5).[9]

Nasoalveolar molding (NAM) devices

The advent of digital technology has also impacted the treatment regimen for individuals with cleft lip and palate. These advancements, designed to lower the aspiration risk with the use of a scanner, appear to enable the physician to make appliances faster and with less labor.

Shen *et al*. employed CAD software. (Rapid Form program, 2006; INUS Technology, Seoul, Korea) to construct orthopedic devices based on the treatment protocol developed by Grayson and Cutting. The software was obtained through scanning models of patients who had alginate imprints.

The objective of these specialized plates is to gradually decrease the gap between the alveolar bones by 1 mm every week, employing 3D-printed representations of the upper jaw.

The study's findings were consistent with traditional NAM therapy, even though there was a reduction in the frequency of clinic visits and the time required for device adjustment (Figure 6).[10]

Limitations

- Costs of equipment
- Limited supply of materials
- Needs for post-processing
- Costs of manufacturing
- Insufficient internal resources for additive manufacturing
- A deficiency in knowledge and/or instruction among workers
- Low repeatability (variability in precision between builds)
- Absence of official guidelines
- Insufficient evidence of the capabilities of additive manufacturing
- Capabilities and software development
- Extended production schedules
- Low capacity for recycling
- Possibility of legal action or ramifications
- Needs for data storage.[11]

Conclusion[1,11]

The integration of 3D printing technology in orthodontics has revolutionized the field by enhancing precision, efficiency, and patient outcomes. From fabricating clear aligners and customized brackets to producing surgical guides and study models, 3D printing streamlines treatment planning and execution. This technology not only reduces material waste and production time but also allows for greater personalization of orthodontic appliances. As advancements continue, including the development of biocompatible materials and AI-driven design automation, 3D printing is set to further transform orthodontic care. Embracing this innovation will enable orthodontists to provide more effective, cost-efficient, and patient-centric treatments in the future.[1,11]

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