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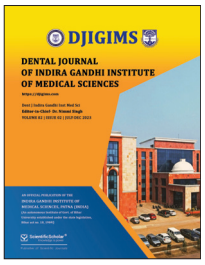
Dental Journal of Indira Gandhi Institute of Medical Sciences

Article in Press



Review Article

3D Printed Customized Bracket Prescription: A Way Ahead

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Received: 25 June 2024

Accepted: 03 August 2024

EPub Ahead of Print: 04 September 2024

Published: ***

DOI
10.25259/DJIGIMS_14_2024

Quick Response Code

ABSTRACT

Since the late 1970s, orthodontists have mostly relied on established manufacturing corporations to produce their appliances. Orthodontics is undergoing a paradigm change from alginate imprints and plaster models to digitized intraoral scanners and three-dimensional (3D) printed models. Orthodontists may now manage their office overhead and treatment planning individually and, in many situations, become their own makers of a wide range of equipment.

Customized brackets fabricated using 3D printing technology with ideal physical attributes help move the teeth into the desired position, allowing for patient-specific application, predictable results, and reduced treatment durations. 3D printing also allows innovative bracket designs that can potentially lead to new treatment approaches and biomechanics. 3D printing technology continues to transform the patient and doctor experiences, ushering in a new era of digital treatment planning, customization, and efficiency.

Keywords: 3D printing, Additive manufacturing technology, Customized brackets, 3D technology application in orthodontics, 3D printed orthodontic brackets

INTRODUCTION

Traditionally, most orthodontic appliances were designed and fabricated in a laboratory setting. Depending on the kind of appliance, acrylic, wires, bands, soldering materials, premanufactured appliance pieces, and wax were used [Table 1].

Many elements of an orthodontic laboratory have now moved into the orthodontic clinic due to recent advancements in digital technology. With the advancement of modern three-dimensional (3D) technology, technicians, dentists, and orthodontists may now develop a range of appliances using computer-aided design (CAD) software, which can then be sent out for 3D printing to either in-office 3D printers or specialized laboratories equipped with various types of 3D printers.

3D PRINTED CUSTOMIZED BRACKETS

Metal and ceramic brackets on the market today are manufactured utilizing procedures such as casting, injection molding, milling, and sintering. The material and manufacturing process used affects not only the final quality of brackets but also their precision in delivering orthodontic forces to the teeth.[1,2] Even a small change in slot height results in a significant rise in the archwire-slot play, which reduces the torque applied to the teeth. Dimensional imprecision in orthodontic brackets, notably slot height, can also affect the archwire-slot play. In extraction

Table 1: History of 3D printing in orthodontics.

Year	Event
1980	Three-dimensional printing was invented by Hideo Kodama of Nagoya Municipal Industrial Research Institute, Japan. He created 3D plastic parts by photo-hardening polymers with UV exposure.
1983	Charles Hull developed stereolithography, in which layers were added by curing photopolymers with ultraviolet lasers.
1986	Hull co-founded 3D Systems, Inc. (Rock Hill, SC) to introduce the technology into the market.
1987	First-ever 3D printer, the SLA-1®, was introduced
2015	LightForce Orthodontics developed a proprietary 3D printing method to generate completely personalized orthodontic brackets adapted to each patient's unique dental anatomy.

SLA-1: Stereolithography (SLA) printer.

cases, an appropriate torque expression is especially crucial since sustaining the torque on the anterior parts is required to enable effective space closure. Torque control is also essential for bucco-lingual root movements, like in cases of ectopically erupted teeth.

CAD/CAM technology has enabled the production of biocompatible resin brackets as an alternative to mass-produced brackets. Given the accuracy of the printing process presently attained by additive technology by modern 3D printers for dental usage, the latter may outperform the former in many ways. The CAD/CAM technology allows for customization and fabrication of aesthetic brackets, making it a more practical approach. Precise bracket placement is crucial for an ideal orthodontic treatment.

Accurate positioning of brackets is key for ideal orthodontic treatment. Any large deviations may result in abnormal root–bone relationship, axial inclination, crown torque, fenestration, and dehiscence. Customized and patient-specific orthodontic brackets may be created utilizing 3D printing technology, with outstanding physical attributes for moving teeth into the desired position. Over the last century, orthodontic brackets have progressed from basic tooth attachments to highly adjustable fixed equipment with pre-adjusted prescriptions.[3]

The next step in treatment efficiency is the use of customized patient-specific brackets. They use intraoral scans and orthodontic simulation software to create brackets with optimal physical properties to move teeth into the correct alignment. Previously, customized brackets were constructed of metal and created using traditional processes, but recently, 3D printing has been used.

A 3D-printed orthodontic bracket system uses additive manufacturing technology to create customized brackets tailored to a patient's specific dental anatomy. This approach offers several advantages over traditional methods of producing orthodontic brackets, such as casting or milling.

Manufacturing begins with the virtual design of each bracket, which is designed to conform perfectly to the architecture of the lingual/palatal surface of teeth. Individual bracket prescriptions for each patient may be made utilizing the digital design, which enables customizing the in-out, angulation, and torque parameters of each bracket. The next phase is rapid prototyping, which converts virtually generated brackets into personalized brackets that may be used for therapy.

3D PRINTED LINGUAL BRACKETS

During the last two decades, the public's desire for a beautiful smile, particularly from adult patients seeking a more cosmetic way to straighten their teeth, has spurred the development of lingual orthodontics. As a result of this growing public demand, significant improvements in laboratory techniques have taken place, increasing accuracy and predictability and removing many of the challenges that lingual orthodontics had previously faced. The lingual technique has traditionally been a laboratory-dependent system, relying heavily on the technician's experience and precision at each stage of the laboratory operation, as opposed to the labial technique, which allows the orthodontist to place brackets directly.

Customized appliances created using CAD/CAM are the future of lingual orthodontics. These appliances allow customization of the bracket base according to the tooth surface, as well as suitable tip and torque prescription, using cutting-edge (CAD/CAM) software and highly evolved rapid prototyping techniques.[4]

The customized bracket base covers the majority of the lingual tooth surface, allowing perfect placement according to the contour of the tooth. Because the wires and brackets are custom-made for each patient, tooth movements are more predictable, eliminating the most challenging aspect of traditional lingual appliances—the orthodontic finishing of each particular case. The brackets are meant to be as low profile as possible, resulting in a more aesthetically pleasing look.

An overview of how a 3D printed orthodontic bracket system works

1. Scanning and Imaging: The process begins with the patient's teeth being scanned using intraoral scanners, which create a digital 3D model of the patient's teeth and surrounding oral structures [Figure 1].
2. Digital Design: Orthodontic specialists or technicians then use specialized software to design the brackets based on the digital scans. This design process takes into

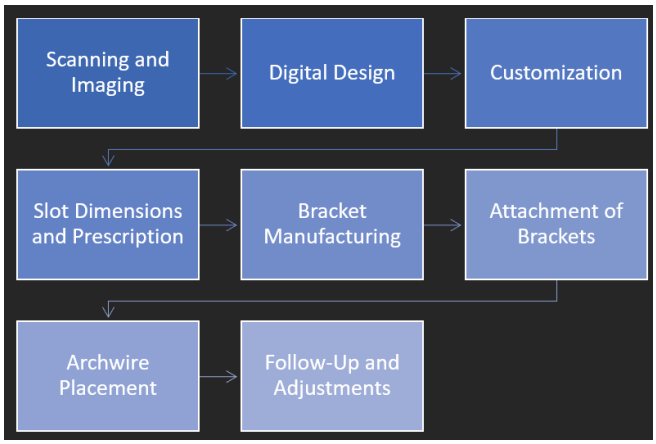

Figure 1: Overview of how a 3D printed orthodontic bracket system works.

consideration the patient's unique dental anatomy, the desired treatment plan, and the biomechanics of tooth movement.

3. Customization: 3D printing technology permits a high level of customization as each bracket can be tailored to fit the patient's teeth precisely, optimizing the bracket's placement and improving treatment efficiency [Table 2].
4. Slot Dimensions and Prescription: The slot in the bracket where the archwire fits can be designed with specific dimensions and prescriptions to facilitate controlled and accurate tooth movement. This customization helps achieve the desired treatment outcomes more effectively.
5. Bracket Manufacturing: The digital bracket designs are sent to a 3D printer that uses various materials suitable for orthodontic applications, such as biocompatible resins or metals. The printer adds material layer by layer to create the brackets according to the precise specifications.

Table 2: Benefits of a 3D printed orthodontic bracket system.

Customization	3D printing enables a high level of customization, resulting in more precise bracket fit and improved treatment outcomes.
Efficiency	Reduce the need for adjustments and potentially shorten the overall treatment duration.
Patient Comfort	Custom-designed brackets are more comfortable for patients and tailored to their unique dental anatomy.
Reduced Chair Time	need for adjustments and modifications during appointments minimized due to the accurate fit of 3D printed brackets
Innovation	allows for innovative bracket designs that can potentially lead to new treatment approaches and biomechanics

6. Attachment of Brackets: Once the 3D printed brackets are ready, they can be bonded to the patient's teeth using orthodontic adhesives, similar to traditional brackets. The brackets are positioned based on the treatment plan.
7. Archwire Placement: After the brackets are attached, orthodontists insert an archwire into the slots of the brackets. The archwire applies controlled forces to guide the teeth into their desired positions over time.
8. Follow-Up and Adjustments: Like traditional orthodontic treatments, the patient will need regular follow-up appointments for adjustments and progress assessments. During these visits, archwires may be changed or adjusted to continue guiding tooth movement.

3D PRINTED INDIRECT BONDING TRAYS

Using specialized CAD software, orthodontists design the ideal placement of brackets on the digital model. The software helps determine the optimal position for each bracket to achieve the desired orthodontic outcome.[5,6,7] This tray is then produced using a 3D printer. The tray holds the brackets in the exact positions, ensuring precise placement on the teeth.

According to Plattner *et al.*[8] using digitally and conventionally created indirect bonding trays resulted in a much shorter active working period in 3D-printing technology than in conventionally produced trays. Except for vertical transfers, 3D-printed trays outperformed traditional transfer technique PVS trays.

Using CAD-CAM, Xue *et al.*[9] created a unique and revolutionary guided bonding technique that accurately transferred the anticipated bracket location from the computer set-up to the patient's teeth.

Bachour *et al.*[10] showed a high degree of positional accuracy in the mesiodistal, buccolingual, and occlusal dimensions by indirect bonding using 3D-printed tray transfers from the digital set-up to the patient's dentition. However, the precision of torque, tip, and rotation correction remains disputed.

CONCLUSION

Orthodontists are progressively depending on 3D printing, and the technology's potential applications are quickly extending. An orthodontist can use a 3D printer to create a completely advanced workflow. Although all these innovations have shown equal or superior results over conventional methods, further research is required to fully understand the clinical benefits and limitations in the field of orthodontics. Future research must recognize potential 3D-printing technology specific to different orthodontic strategies.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patient consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Mani S, Manerikar R, Thorat A. 3D Printed Customized Bracket Prescription: A Way Ahead. Dent J Indira Gandhi Int Med Sci. doi: 10.25259/DJIGIMS_14_2024