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A Revolution in the Making: A Review of the Use of 3D Printing with Orthodontic Appliances

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ABSTRACT

3D printing revolutionizes orthodontic appliance creation, producing customized braces and appliances with unmatched precision for faster, accurate orthodontic outcomes. The efficiency of 3D printing significantly cuts patient waiting times, crafting appliances in hours instead of weeks. This article reviews the appliances that can utilize 3D printing such as diagnostic models, removable appliances, pre-surgical nasoalveolar moldings, occlusal splints, space maintainers, expansion devices, customized brackets, indirect bonding trays (IDT) and retainers. This emergent 3D technology has had a transformative effect on the field of orthodontics but still has challenges and considerations in its application.

Keywords

3D printing in orthodontics, Braces and aligners, Orthodontic appliances, Customizable orthodontics.

Introduction

Presently, with the emergence of computer-aided design and three-dimensional (3D) technology, craniomaxillofacial dental care and specifically orthodontics is poised to become revolutionized in it's service delivery, production of appliances and workflow in practice settings. Archwires, nasoalveolar molding devices, removable appliances, clear aligners, expansion appliances, auxiliary attachments, orthognathic surgical splints and casts can all be made with 3D technology [1]. Orthodontists now have access to this mode of producing appliances which has increased production and allow for customizable options for patients. With the use of intraoral scanners and 3D printing, the need for dental impressions has been completely eliminated, and now orthodontists can provide a fully digitalized model in orthodontic service delivery. Dental impressions remain the mainstay of record making and treatment planning, and now that this task can be done digitally, efficiency and workflow in orthodontic practices have improved. Another valuable feature of 3D printing is that patient-specific designs from 3D printers allow orthodontists to develop viable solutions that no longer require visual estimates for their dimensions.

Discussion

A thorough orthodontic diagnosis requires comprehensive 3D analysis of the interrelationships among the dentition, craniofacial skeleton and soft tissues. 3D printing technology will provide more than 60% of all dental treatment needs by 2025, and orthodontic companies as well as remote monitoring companies are already using AI technology, being it essential that the clinicians are prepared and knowledgeable with the technology advances now available [2]. 3D printing offers a precise way to fabricate appliances layer by layer, allowing for better accuracy in the fit of appliances and better patient compliance [3]. In orthodontics, often

patients anatomical anomalies are variable, and cases can become very complex from case to case. With the ability of 3D printing to customize devices for e.g. the chains used to move impacted teeth or spreaders for a vaulted palate, when conventional dimensions are not present, 3D printing can effectively measure these intricate differences down to the micron creating appliances that are far better at fit when compared to laboratory fabricated appliances [4].

The use of 3D printing with Orthodontic Appliances

3D printing can be effectively utilized in the fabrication of the following appliances: diagnostic models, removable orthodontic appliances, pre-surgical nasoalveolar molding, occlusal splints, space maintainers, expanders, aligners and retainers.

Diagnostic Models

Diagnostic models measurements performed with 3D digital models represent high validity, reliability, and reproducibility. They are a viable alternative to traditional plaster models and identical copies of a digital model can be reproduced without distortion or deformation which can negatively affect the appliance that is built upon it [5]. Warping and distortion are two common issues traditionally encountered using gypsums and other polymer materials when used for dental impressions.

Removable Orthodontic Appliances

Removable Orthodontic appliances that can be fabricated by 3D printing include the Hawley appliance and functional appliances like Twinblock or activators. Traditional pouring of plaster casts has effectively been eliminated by utilizing scans such as TRIOS™ or 3Shape™ [6]. Other manufacturers worldwide of 3D orthodontic appliances include DentalWings™, Shining 3D™, Medit™ and EnvisionTEC™.

Pre-Surgical Nasoalveolar Molding

The area of orthognathics has also benefited from 3D printing. Treatment protocols for patients requiring reconstructive surgery have appliances that are better adapted to facial structures, which leads to less aspiration of material, and quicker planning and fabrication by clinicians. Alveolar ridges can be clearly identified and measured using a graphical user interface and design plates, which are able to mimic the growth of bones in healthy newborns requiring molding devices. These design plates can be made in just a few minutes and adapted to the area in need of treatment [7].

Occlusal Splints

Occlusal splints have traditionally been utilized when treating patients who present with temporomandibular disorders (TMD) and orthognathic asymmetries. Subtractive technology, where a block of acrylic is reduced to a desired shape and size was originally used to fabricate occlusal splints. But 3D printing has offered a different method, called Additive technology, where acrylic layers are added on to each other, while bonding occurs between levels to fabricate an appliance [8]. This method has proven to be faster, more adaptable and better fitting for patients.

Space Maintainers: Transpalatal arch, Hybrid Nance appliance and Lingual arch appliances

Space maintainers are used to intercept malocclusion before it is established within the dentition of a child receiving orthodontic care. The following appliances are also used for anchorage reinforcement, where a tooth or teeth must be held stationary during treatment until movement can be elicited. These appliances can now be routinely fabricated with 3D printing: a) Trans palatal arch is 3D printed through metal printing and the bonding site is designed on the molars not completely circular, but only confined to palatal surface. b) Hybrid Nance appliance: Nance appliance again serving both purposes, can be 3D printed through metal printing. c) Lingual arch: Lingual arch fabrication with bands designed to be printed through 3D metal printing (fully or partial) around the molars with a connector along the lingual surface of the teeth [9].

Expansion Appliances

3D printing has seen much success with expansion appliances that shorten treatment times and adapt better. Rapid Palatal Expanders (RPEs) have been designed in various ways, with the most common forms being a single or connected band(s), bands with arms or a faces mask where the arms are equipped with hooks that attach to elastic intraorally and anteriorly [9,10]. There are also modifications to expansion appliances and distalizers, appliances used to gently push maxillary molars backwards as seen with 3D printed Hyrax-Hayrake-Blue-grass combination appliance, an appliance that is a combination of three appliances: the hyrax, a split hayrake for habit-breaking and a movable bluegrass bead for tongue training [9].

Customized, Patient-specific Orthodontic Brackets and Indirect Bonding Trays (IDB)

When 3D printing is utilized to fabricate customized orthodontic brackets, they are usually made from polycrystallines alumina ceramic or metal and 3D printed into twin brackets with idealized geometries, which creates tooth movement that is highly efficient. Customization can also be extended to self-ligating and lingual brackets and indirect bonding trays which are used to accurately place brackets onto teeth prior to bonding [11].

Retainers

Retainers such as the Clear/Essex thermoformed polymer retainers can be fabricated with high efficiency through 3D printing. When a retainer is needed to be bonded to several teeth surfaces lingually, 3D printing can also be used to measure and reproduce the metal bar used for permanent bonding to the surfaces of teeth. The process of fabrication of these types of retainers has greatly benefited from the precision and customization of 3D printing due to the unique shapes and alignment of a patient's teeth post-orthodontic treatment [12].

Figure 1: 3D printed dental models for several patients.

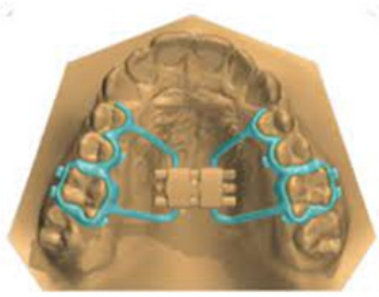

Figure 2: Planning of a Hyrax appliance in 3Shape™ 3D Software.

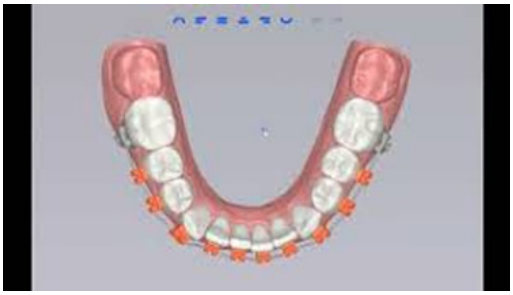

Figure 3: Planning for Customized Brackets in Orthodontic System Software 3Shape™.

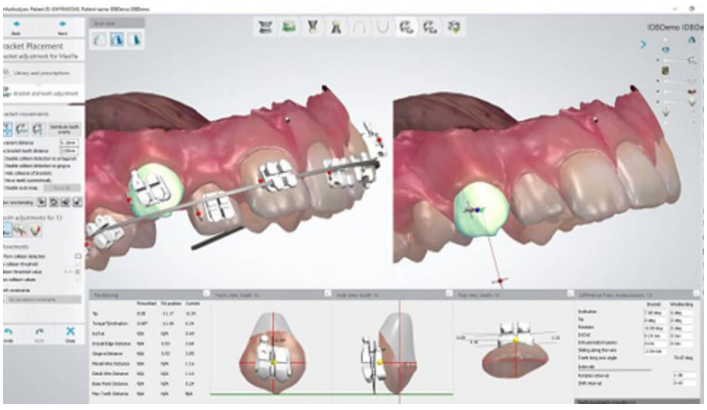

Figure 4: Orthodontic system Software 3Shape™ used for Treatment Planning a Case.

Figure 5: Hawley Retainer on 3D model.

Conclusion

As the field of orthodontics continues to evolve, 3D printing technology holds the key to revolutionizing this specialty in its service delivery, cost cutting and providing a better patient experience. Appliances have become highly adaptable and customized for patients. As 3D printing and other digital technologies continue to emerge and further improvements within orthodontics, innovations and better dental outcomes are expected. 3D printing technology has made orthodontics more efficient, and this in turn has made the field more affordable for patients where orthodontic treatment might have been out of reach. Digitization represents a radical shift in thinking within the field of orthodontics, where orthodontists are now able to provide dental care that is precise and personalized for each patient; and though this was the case before, the customization is now more precise and empirical. This precision translates to more predictable outcomes for patients and higher success rates for orthodontic cases.

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