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Review Article

Material Properties and Clinical Performance of 3D-Printed Complete Dentures: A Systematic Review

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Abstract

The creation of complete dentures using the additive tri-dimensional (3D) printing technique has gained popularity in recent years. Although the technological components of this relatively new technology are fully developed, the therapeutic aspects of its application are still being developed. Given their clinical use, the objective of this review was to evaluate the information currently available in the dental literature on the quality of 3D-printed complete dentures and highlight the areas that are both clear and unclear. Three databases were used for the electronic search: PubMed, Scopus, and Web of Science. The findings indicate that the clinical characteristics of complete dentures created using 3D printing additive technology have not been thoroughly investigated. The best technical parameters for the technological application and the mechanical properties of materials for 3D-printed removable dentures are hot topics. However, there are still many obstacles to overcome in the prosthetic rehabilitation of completely edentulous individuals using 3D-printed dentures. These include the attainment of optimal fitting to the denture-bearing region, adequate masticatory function, and the accurate vertical dimensions of occlusion when employing fully digital clinical procedures. The problem of achieving predictable aesthetic results remains unresolved. Further research is needed to clarify these aspects of the clinical performance of 3D-printed complete dentures.

Key words: 3D-printed complete dentures, 3D-printing materials, Denture base accuracy, Patient satisfaction

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Introduction

The primary goal of prosthetic treatment for patients who are completely edentulated is to restore their masticatory and speech function as well as their aesthetic appearance. A number of factors that have been extensively discussed in dental literature determine how satisfied patients are with complete dentures; they are most unhappy when dentures cause pain, have poor retention, move, or fall during mastication, making it difficult for them to chew, especially hard food [1, 2]. According to studies on patient complaints, 15–20% of patients express problems with the stability and retention of their dentures [3]. Following total tooth loss, the restoration of the patient's aesthetic appearance following their needs is also crucial to the success of denture treatment [2]. We have developed clinical procedures that involve characterizing each denture to attain good cosmetic results.

The technique used to create full dentures has an impact on their functional characteristics. As of right now, we are aware that the majority of these problems stem from clinical studies of individuals who had traditional complete dentures that were developed using conventional technology. In modern dentistry, the clinician may favor some cutting-edge digital techniques over traditional ones because of the rapidly evolving digital technologies. We have suggested several strategies, including computer-assisted techniques, for creating complete dentures [4, 5]. The scientific community has reached a consensus regarding several benefits associated with using the digital protocol for the creation of complete dentures. Less time spent dealing with the patient and fewer clinical visits are the two main benefits of traditional approaches [6].

The use of tri-dimensional (3D) printing in the additive approach to create entire dentures has grown in popularity in recent years [7]. Although the technological components of this relatively new technology have been thoroughly developed, the therapeutic aspects of its application are still being developed. Nowadays, a lot of study is focused on finding a way to produce a product that is clinically predicted in terms of quality and functional fitness.

Complete dentures designed using digital technology are thought to have superior mechanical qualities, consistent plate thickness across their various regions, and improved conformance with the denture field [8, 9]. As a result, there are fewer traumatic mucous membrane lesions associated with wearing dentures [10]. Other authors, however, disagree that dentures developed using digital technology are suitable in terms of stability, adaption, and retention. The rationale for the differing views is that, when dentures were created using computer-assisted techniques, inaccuracies in the denture edge location were frequently discovered [11].

When entire dentures are being built using digital technology, another contentious topic is how precisely we could replicate occlusal connections in the various occlusal schemes [12]. For both milled and 3D-printed complete dentures, we have published results with similar accuracy. Another topic under discussion is the extent to which therapeutic procedures utilizing additive technology and a fully digital approach guarantee that patients' aesthetic preferences are met [13].

Even though multiple researches show the advantages of digital technologies, there are critical doubts about the quality of entire dentures manufactured via additive technology of 3D printing which have still not been fully addressed.

Given their clinical use, the objective of this review was to evaluate the information currently available in the dental literature on the quality of 3D-printed complete dentures and highlight the areas that are both clear and unclear.

Materials and Methods

E-search was performed in three databases: Web of Science, Scopus, and PubMed. The keywords used were “3D-printed denture accuracy,” “3D-printed dentures base properties,” “3D-printed dentures biocompatibility “, “3D-printed dentures aesthetics”, “Patient satisfaction with 3D-printed dentures.”

It was performed screening of the extracted articles based on the inclusion and exclusion criteria as follows:

Inclusion criteria

1. Research with a focus on 3D-printed dentures.
2. In Vivo and In Vitro studies.
3. English language of publication.
4. Articles published between 2018 and 2023.

Exclusion criteria

1. Publications other than the English language.
2. Articles published out of the period 2018-2023.

Results and Discussion

To shed light on the benefits and drawbacks of additive technology, we have examined many aspects of full 3D-printed dentures and contrasted them with those of dentures made using conventional and other digital techniques [11, 14].

Retention and stability of 3D-printed dentures

One of the most crucial elements for the durability and retention of full dentures is without a doubt the accuracy with which the denture base fits the denture-bearing region. The precision of denture bases made using 3D printing and denture bases made using other technologies are compared in several studies.

Hwang *et al*. [15] compare the adaptation of upper dentures' internal surfaces prepared via three different technologies. The internal denture surfaces have been scanned and compared via the method of computer superimposing with the surface of the corresponding casts. The group of 3D-printed dentures demonstrates better trueness (0.074 ± 0.005) and adaptation of mucous surface compared to the group of Compression molding (0.165 ± 0.056) and the milled dentures (0.177 ± 0.003).

According to other studies, the denture base made using additive technology has better retention than the one made using thermal polymerization. The experimental bases of maxillary complete dentures show trueness values of 0.02 ± 0.08 for those made using compression molding and 0.03 ± 0.01 for those made using 3D printing [16]. Lee *et al*. [17] compare the accuracy of maxillary dentures made using compression molding, milling, and 3D printing, and the precision of the denture base is higher in the case of milled and 3D-printed dentures than in the case of injection molding.

The majority of authors, we can assume, agree that 3D-printed denture bases are more true to life than those made with compression molding. However, no universally accepted method ensures greater denture base trueness when comparing milled and 3D-printed dentures.

A comparison of ten milled and ten 3D-printed upper complete dentures with their intaglio surfaces scanned using a lab scanner reveals that the 3D-printed dentures have greater trueness [18].

Different findings are reported by Lo Russo *et al*. [19], who compared the trueness of the intaglio surface of complete dentures prepared using two technologies, namely milling and 3D printing, and an entirely digital protocol. The dentures were scanned using the same intraoral scanner that was used to scan edentulous jaws. The zones of interest were marked at predetermined points at which comparative measurements were taken. According to the authors [19], the 3D-printed dentures (0.018 m) show less variance in the studied zones of interest than the milled dentures, which generally show superior trueness of the entire internal surface (0.002 mm).

When considering the stability and retention of a full lower denture, the importance of the denture base's adjustment to the denture-bearing region is even higher. Due to the complete lower dentures' lack of stability during mastication, which results in pain and discomfort when attempting to chew food, the majority of patient complaints are connected to this use [20].

The precision of lower dentures made by compression molding, milling, and 3D printing is compared by Yoon *et al*. [21]. Through the use of 3D software, the inside surfaces were scanned, and the degree of adaption was evaluated by superimposing them over the matching models (3D comparison software Geomagic Verify, 3D Systems). Although there is no statistically significant difference in the adaptation to the denture bearing area, the milled dentures have shown superior trueness (0.104 ± 0.015) than the 3D printed dentures (0.101 ± 0.011).

Researching the accuracy of a few crucial areas that directly affect dentures' stability and retention in greater detail is crucial to obtaining objective results when assessing the quality of 3D-printed dentures.

The adaption of entire denture bases created using three different methods—conventional technology, milling, and 3D printing—is compared by Masri *et al*. [14]. The milling approach offers the optimum adaptability in the majority of locations, according to a study on five functional areas: the maxillary tuberosities, palate, crest of the ridge, anterior border seal, and posterior palatal seal. The distal palatal parts are where 3D-printed bases adapt the best, which is crucial for the full upper denture to be retained well.

A different study finds no difference between the 3D-printed dentures' adaption and that of the milled and compression-molded dentures. While the thickness of the silicon layer was assessed using a stereo microscope, the fitting of dentures was measured using the silicone replica approach. There are no statistically significant variations in the measurement points using this methodology [22].

Flexural strength is another metric used to assess the denture bases' quality. We have examined the flexural strength of trial specimens made by 3D printing and milling in an in vitro study, using both a third-party 3D printer and the manufacturer's recommended printer [23]. The flexural strength of the milled dentures is greater than that of the 3D-printed ones. The flexural strength of dentures made with the manufacturer's suggested printer is higher than that of dentures made using a third-party printer's help.

Technological aspects influencing the quality of 3D-printed dentures

Gad and Fouda [24] conducted a systematic review of the factors influencing the flexural strength of 3D-printed resins and concluded that one or more of the following factors could improve this property: the thickness of the printing layer; post-polymerization time and temperature; the addition of nanofillers; and printing orientation, angulation, or directions.

The accuracy of the denture foundation as well as the stability and retention of full dentures may be impacted by the 3D printing process. In light of this, crucial elements were covered about layer thickness and various build orientation settings. The trueness of the base of 3D printed mandibular dentures made with various build orientation settings—0◦, 45◦, and 90◦—is compared by Gao *et al*. [25]. They discover that the dentures made with 45◦ build orientation exhibit the best trueness of fit. Additionally, 45◦ construction orientation exhibits the maximum accuracy, according to Hada *et al*. [26].

Additionally, we looked into how layer thickness affected the precision of denture bases made using a DLP 3D printer (Pro95, SprintRay, USA) and the denture base material DENTCA Denture Base II, Dentca, USA [27]. In addition to two types of layer thickness (50 µm and 100 µm), they have examined the findings in seven build orientations (0°, labial 45°, labial 90°, posterior 45°, posterior 90°, buccal 45°, and buccal 90°). Optimizing this parameter could improve the accuracy of 3D-printed dentures. It was discovered that the denture bases printed with labial orientations of 45° and 90° exhibit the maximum accuracy. The layer thickness does not affect accuracy; it simply affects printing time.

The majority of authors support the idea that 3D-printed dentures should be developed with a 45° build orientation to attain the highest level of precision. However, Jin *et al*. [28] think that denture adaptation is unaffected by construction angle settings. When assessing how well the different denture groups adapt to the application build angle, the authors examine the effects of different build angle settings—90, 100, 135, and 150—on the mucous surface adaptation of ten upper and ten lower complete dentures. They do not discover any statistically significant differences.

There may be other technological quirks that affect the quality of the 3D-printed denture foundation. According to Lee *et al*. [29], the mechanical and biological characteristics of 3D-printed dentures may potentially be impacted by the use of different (vat) polymerization processes. They study NextDent denture bases that are created using digital light processing, light-crystal display, and stereolithography and that go through the same post-polymerization processes. The authors have assessed water absorption and solubility, flexural strength and modularity, strength to fractures, and fungal adherence. The stereolithographically printed bases provide the maximum flexural strength. When printing using digital light processing, the water absorption and solubility are much higher, and stereolithography was shown to have the highest fungal adherence. The authors concluded that various polymerization procedures for 3D printers may be used to treat 3D-printed resins if the light wavelength was appropriate.

The effect of post-polymerization on a 3D-printed polymer (V-Print database, VOCO) for denture bases is another aspect that has been studied. Using several light-curing devices (Otoflash G171, Labolight DUO, PCU LED, and LC-3D Printbox), it investigated how post-curing techniques affected surface properties, flexural strength, and cytotoxicity. Although the various post-curing techniques have little effect on surface roughness and topography, they have the potential to improve flexural strength and successfully lessen the cytotoxic effect of 3D-printed polymers [30]. Additionally, we have examined the outcomes of applying several post-polymerization regimes to 3D printed specimens that mimic full maxillary dentures: time: 15 and 30 minutes; temperature: 40, 60, and 80 °C. It has been determined that 30 minutes and 40 °C are the ideal post-polymerization times and temperatures for 3D printing, respectively [31]. These requirements are necessary for both effective adaptation and high denture base conformance with the denture-bearing region.

The effects of printing orientation and post-curing time on the surface roughness and hardness of two 3D-printed materials (NextDent and ASIGA) and traditional heat-polymerized material are examined by Al-Dulaijan *et al*. [32]. Different orientations were used for printing: 0°, 45°, and 90°. Each group of samples was subsequently exposed to four post-curing regimes (30, 60, 90, and 120 minutes) and 10,000 cycles of thermocyclic processing. The 3D-printed specimens' surface roughness is unaffected by the printing orientation or the post-curing duration. The hardness of 3D-printed materials is generally lower than that of conventional materials; this could be enhanced by extending the post-curing period to 120 minutes.

Properties of the materials for elaboration of 3D-printed dentures

The qualities of the material used to create dentures, in addition to technological factors, determine their quality. For the denture base, Casucci *et al*. [33] compare the flexural strengths of eleven distinct materials: A 3D-printed composite resin (GC Temp Print), two milled denture resins (Ivotion disc and Aadva disc), two 3D-printed PMMA NextDent Denture 3D+, and one traditional PMMA resin (Acrypol R, Acrypol LL, Acrypol HI, Acrypol Fast, Acryself, and Acryslef P). Since all of the 3D-printed materials showed a strong correlation between the polymerization technique and flexural strength, the best selection may be pivotal. The materials for milled dentures exhibit the highest flexural strength, followed by the 3D-printed composite resins.

The flexural strength and surface hardness of various materials and technologies are compared in vitro for the development of denture bases: one polyamide material (Vertex ThermoSens), milled dentures (IvoBase CAD, Interdent CC disc PMMA, and Polident CAD/CAM disc), 3D-printed dentures (NextDent Base), and heat-polymerized dentures (ProBase Hot, Paladon 65, and Interacryl Hot) [34]. Significant variations were discovered concerning the characteristics of the study. The flexural strength of the material used for 3D printing is the lowest. According to Prpić *et al*. [34], materials for milled dentures often exhibit superior mechanical qualities when contrasted with those for 3D printing and heat-polymerization. DentaBASE (ASIGA, Erfurt, Germany), Denture Base Resin LP (Formlabs Inc., Somerville, MA, USA), and Denture 3D+ (NextDent B.V., Soesterberg, Netherlands) are three experimental 3D-printed materials whose flexural qualities and printing accuracy are compared to those of specimens made of heat-polymerized resin in another study [35]. Depending on the material, variations in length range from 1.3% to 2.4%, width from 0.2% to 0.7%, and thickness from 0.2% to 0.6%. The flexural strength and module of elasticity of the 3D-printed specimens are lower than those of the heat-polymerized ones. The material selection was found to affect printing accuracy and, to a lesser extent, flexural strength, but not the elasticity module.

Biological and antimicrobial properties

The biocompatibility and antibacterial qualities of materials used to create full dentures are also influenced by their mechanical characteristics. To decrease bacterial biofilm and enhance patient aesthetics and denture reception, the denture base's low surface roughness is a crucial requirement [36].

It is commonly known that the primary symptom of denture stomatitis is prolonged inflammation of the mucous membrane of the denture-bearing area, which is most frequently brought on by the growth of *Candida albicans* colonies [37]. This affects the patient's overall health as well as their oral health. To decrease *C. albicans*' ability to adhere to denture surfaces, low porosity, and superficial roughness are crucial [38]. Compared to dentures created using computer-assisted technologies, conventional dentures, even after meticulous washing and polishing, generate conditions for improved *C. albicans* adherence [39]. It has been demonstrated that 3D-printed and CAD/CAM dentures are less porous than traditional PMMA dentures [39, 40].

According to the most recent research, the mechanical and antibacterial qualities of materials can be greatly enhanced by modifying them for 3D printing with various agents in the form of nanoparticles. The flexural strength, impact strength, surface roughness, and hardness of 3D printed resins containing silicon dioxide nanoparticles are assessed by Gad *et al*. [41]. The findings show that without raising the surface roughness, this modifying agent enhances the attributes under investigation. While ZrO_2 NPs did not affect the surface roughness of the 3D-printed resins, Khattar *et al*. [42] found that their inclusion at low concentrations (0.5%) dramatically decreased *C. albicans* adhesion and proliferation.

They have assessed the effects of two types of 3D-printed resins modified with the addition of zirconium dioxide (ZrO_2NPs) nanoparticles on specimens' flexure strength, elastic modulus, impact strength, hardness, and surface roughness [43]. When compared to the heat-polymerized resins, the unaltered 3D-printed resins show a notable decline in every investigated property. The flexure strength, impact strength, and hardness of the modified 3D-printed materials have risen, although the elastic module and surface roughness have not changed much.

For dentures to be functionally fit, the ideal occlusal parameters must be determined. The majority of CAD/CAM systems allow for the usage of a virtual articulator. The accuracy of the fully digital approach to establishing the occlusion parameters in the situation of complete edentulation has not yet been addressed, and the study findings in this area that have been published in the dental literature are incongruous. The likelihood of a vague characterization of the vertical dimensions of occlusion is the main issue. Another crucial issue is the accurate replication of occlusal contacts following the chosen occlusal scheme.

In this study, we examined the variations in occlusal forces between CAD-CAM and 3D-printed complete dentures that were developed using several occlusal schemes, including bilateral balanced, lingualised, and mono-plane [44]. Regardless of the occlusal scheme used, it was found that 3D-printed dentures had superior retention when compared to CAD-CAM dentures. The optimal centralization and alignment of forces, as well as the replication of increased occlusal forces during the masticatory function, are provided by the bilaterally balanced occlusion and the lingualised occlusion [44]. Modern technologies offer the possibility of homogeneous occlusal contact distribution, which is crucial for both comfort and temporomandibular joint prevention.

Aesthetical aspects

The information that is now available indicates that because clinical trials are not incorporated into digital protocols, 3D-printed dentures restrict the potential for patients' aesthetic preferences to be satisfied [13]. The visual effect may become less predictable as a result. Furthermore, while there are several possibilities to customize dentures using digital technologies, these are significantly less numerous than the opportunities to describe dentures made using traditional laboratory techniques [13].

Using five dentures created using the injection-molding process and five created using 3D printing, Tasaka *et al*. [45] compare the teeth dislocation that happened after the dentures were finished with the original tooth arrangement onto wax. When comparing 3D-printed dentures to heat-polymerized ones, a larger displacement of the teeth was noted.

Mugri *et al*. [46] investigate how two commercial tobacco products affect the surface roughness and color stability of denture bases made using traditional heat-polymerization, 3D printing, and milling. In comparison to the other study groups, 3D-printed bases showed the biggest variations in color and surface roughness.

Sustainability of complete denture properties

A crucial precondition for the prosthetic treatment's long-term success is the durability of the entire denture's characteristics over time. When utilizing dentures, numerous elements could affect their quality. The denture base may vary as a result of daily exposure to different foods and beverages, washing and disinfection methods, and other factors. This could impair retention, denture stability, appearance, and overall functional fitness. Therefore, to anticipate future developments, it is crucial to evaluate the effects of different conditions on 3D-printed dentures.

Wemken *et al*. [47] compare maxillary dentures made using three different techniques: 3D printing, milling, and injection molding. Hydrothermal treatments and microwave sterilization are used to “age” dentures. Before the “aging” process, milled dentures show the lowest surface variation, followed by injection-molded and 3D-printed dentures. In contrast to injection-molded and 3D-printed materials, the milling group's trueness is unaffected by hydrothermal processing. Microwave sterilization causes noticeable deformations in injection-molded and milled dentures that would be clinically relevant, but it does not affect the 3D-printed dentures' measured trueness.

Using two different kinds of connecting agents, we have assessed the strength of the bond between two kinds of artificial teeth and 3D-printed plates [48]. They discovered that the binding strength for Biotone teeth is comparable to the control group when using simply Cosmos TEMP and much higher when using MMA + Cosmos TEMP. Given a 3D-printed tooth (Cosmos TEMP) the employment of both connecting agents provides outcomes identical to the control group.

In their in vitro study, Alharbi *et al*. [49] compare the failure loads of commercially available denture teeth and traditional heat-polymerized materials with those of 3D-printed denture resin material and teeth both before and after dynamic loading. In a chewing simulation, ten specimens from each group were exposed to a dynamic stress of 50 N for 250,000 cycles. The way that acrylic teeth and resin base material fail is influenced by processing techniques. In the conventional group, cohesive failure in teeth was more common. Both approaches show that the bond between the teeth and base material is strong enough to withstand dynamic loading.

Additional in vitro studies contrast the color stability, surface roughness, and mechanical characteristics of the basis materials for dentures made via heat polymerization and 3D printing [50]. In comparison to heat-polymerizing acrylic resin, the 3D-printed materials exhibit reduced surface roughness and increased impact resistance, but they also have lower flexural strength, hardness, and color stability.

Additionally, it looked at the transparency, solubility, and water absorption of three 3D-printed denture base materials (NextDent, FormLabs, and Asiga) [51]. Both before and after the specimens were thermally processed for 5000 cycles, the measurements were taken. In comparison to the heat-polymerized materials, the three 3D-printed materials exhibit reduced transparency and increased water absorption and solubility. All of the investigated materials' surveyed attributes are adversely affected by thermal processing.

One significant feature of 3D-printed denture base materials that relates to the potential to offer patients long-lasting, comfortable dentures is their reparability. According to Pavlova [52], 54.17% of patients have worn their dentures for more than five years. Under the impact of several causes, precisely elaborated dentures may lose their high-functioning qualities. The underlying tissues may sustain injury as a result of the violation of conformance with the denture-bearing region. Unfortunately, not much is known about this problem. One study assesses how hard-reline techniques affect the flexural strength of materials used in digital denture base elaboration [53]. Three varieties of PMMA for milled dentures and three types of materials for 3D-printed dentures have been compared with conventional PMMA resin. Following rebasing, the flexural strength of all milled denture materials decreases, but that of traditional and 3D-printed materials increases noticeably. The findings show that harsh relining affects the flexural strength of the majority of digitally developed denture base materials.

For the denture foundation, we have also assessed the possibility of repairing 3D printed material (FREEPRINT denture) [54]. They have investigated how shear bond strength is affected by surface treatment and artificial aging. The 3D-printed material exhibits a high capacity for repair. We don't require any more treatment because the shear bond strength is adequate given the rebased surface. Shear bond strength may be considerably reduced in older dentures, hence further processing is advised.

Clinical evaluation of 3D-printed dentures

Few studies were conducted to assess patients' satisfaction following actual 3D-printed denture use. Liu *et al*. [55] polled 30 edentulous patients who were divided into two groups: those with 3D-printed dentures and those with conventional complete dentures. Four times after the dentures were inserted, as well as after one, three, and six months, the patient's satisfaction was assessed using a visual analog scale (VAS) with a range of 0 to 10. After three months of wearing the dentures, all assessed individuals' satisfaction scores showed better values. There are no statistically significant variations in the two groups' assessments of the dentures' stability, comfort, masticatory capacity, speech function, and appearance.

The satisfaction of patients with traditional complete dentures and dentures created using 3D printing is also examined in another clinical study [56]. A wide range of indicators have been assessed, including masticatory efficacy, current pain, stability, retention, comfort during denture use, aesthetics, phonetics, ease of cleaning, and overall satisfaction. Patients indicate more pleasure with conventional dentures because of their phonetics, stability, comfort, and ease of cleaning. About 20% of patients prefer digitally prepared dentures even though their satisfaction is often lower since they require fewer clinical appointments and require less time for elaboration.

20 patients wearing three different types of complete dentures—conventionally created using a conventional impression, additively built using intraoral scanning, and additively manufactured with cast digitization—were compared for satisfaction by Al-Kaff *et al*. [57]. In general, patients are just as satisfied with both kinds of 3D-printed dentures as they are with traditional ones. Compared to previous dentures, particularly those of the mandible, 3D-printed dentures made using only digital impressions have poorer clinical quality and retention. Teeth arrangement with both types of 3D-printed dentures gets lower approval compared to the conventional ones.

Cristache *et al*. [58] surveyed the opinion of 35 patients wearing complete dentures prepared according to an innovative protocol via additive technology and modified PMMA via the incorporation of TiO_2 nanocomposite. The evaluation was performed at 3 stages – 1 week after insertion of the dentures and in 12-, and 18-month period of use. It makes use of the Oral Health Impact Profile for Edentulous Patients (OHIP-EDENT) and the Visual Analogue Scale (VAS, 0-10). During the study era, the novel material offered the chance to create dentures with good functional qualities that maintain their enhanced qualities.

In a review, Alhallak *et al*. [59] examine the practical use of 3D-printed dentures and CAD/CAM in contemporary dentistry. They point out that numerous research suggest more clinical trials provided better results concerning aesthetics, retention, and vertical dimensions of occlusion, in addition to the well-acknowledged benefits like reduced preparation time and generally favorable clinical results.

By comparing the inherent properties of digitally elaborated dentures made using 3D printing with those made using traditional methods, it is possible to determine the extent to which new technologies could contribute to increased patient satisfaction following masticatory system rehabilitation with complete dentures [14-19]. Many studies show superior or equivalent results to those obtained for traditional complete dentures, even though opinions regarding the stability and retention of 3D-printed dentures are not entirely clear.

To determine the accuracy of the denture base of 3D-printed dentures, several studies have been conducted in recent years. We have reason to believe that the given results are more precise than those developed using compression molding [15-17]. However, there are differing views on this characteristic in comparison to milled dentures. According to some studies, the most precise 3D-printed denture bases are [15], while others claim that the milled ones are more precise [19, 21].

The use of a variety of research techniques and the fact that the majority of the studies were conducted in vitro on experimental specimens rather than in the clinical settings of actual patients may be the cause of the confused views around these difficulties. These support the notion that 3D-printed dentures' shortcomings are their strength, appearance, and biocompatibility, and that there is still a dearth of data regarding their clinical behavior under actual oral cavity conditions [60].

Although the results support some of the benefits of modern technologies, there are still important questions regarding the development of complete dentures that have not been resolved. The possibility of obtaining predictable results and the dependability of digital errors are two examples of such problems [61]. The results regarding the characteristics of the 3D-printed dentures may change depending on the clinical protocols used. The possibility of inaccuracies in denture base fitting due to intraoral scanning errors rather than 3D printing must be taken into account when implementing entirely digital protocols. The outcomes of comparable research help the dentist make an informed choice about whether a particular method is appropriate for a given patient.

The majority of the study is focused on analyzing the mechanical characteristics of entire dentures that are 3D printed. We have looked into how several factors affect these qualities and determined the ideal 3D printing parameters to produce high-quality dentures [24-29].

Numerous comparative studies on 3D-printed denture foundation materials discuss their benefits and drawbacks and make material selection easier when creating dentures using the additive approach [24, 34, 35]. The superior mechanical and, most importantly, antibacterial properties of modified 3D-printed materials including nanoparticles from various modifying agents have been elucidated [41, 43, 45]. The development of 3D-printed dentures is intended to make use of this benefit to prevent oral diseases such as denture stomatitis.

Only a small number of research addresses other facets of 3D-printed denture development, like specifying the vertical occlusion and aesthetic dimensions. The consensus is that digital technology might replicate many occlusal schemes with sufficient precision; nevertheless, there is a lack of clinical research that confirms the definition of the ideal restoration of speech and masticatory function as well as the intermaxillary relationship [44].

Another contentious topic is whether or not 3D-printed dentures can produce adequate cosmetic outcomes [13, 45, 46]. The absence of pre-completion denture trials makes it difficult to account for patients' unique aesthetic preferences and reduces the predictability of denture treatment [59]. Given this, more research is required to identify ways to describe 3D-printed dentures.

Results from the clinical use of 3D-printed dentures are reported by relatively few researchers [55-57]. The obtained information is varied and frequently favors milled and conventional dentures over 3D-printed ones [56, 57]. This supports the view that the information currently available is insufficient to make well-reasoned judgments on the rehabilitation of speech function, masticatory ability, and aesthetics concerning 3D-printed dentures.

Conclusion

The qualities of complete dentures created by the additive technology of 3D printing have not been thoroughly examined from a clinical point of view. The best technical parameters for the technological application and the mechanical characteristics of materials for 3D-printed removable dentures are hot topics. However, there are still several obstacles in the way of fully edentulated patients receiving prosthetic rehabilitation with 3D-printed dentures. Among these are the ability to predict aesthetic outcomes, accomplish optimal fitting to the denture-bearing region, and determine the precise vertical dimensions of occlusion when employing fully digital clinical protocols.

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