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Review Article

Application of 3D printing and its various technologies in dentistry

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ABSTRACT

Many applications for these technologies have been reported in multiple fields, including dentistry, within the last three decades. It can be used in periodontology, endodontics, orthodontics, oral implantology, maxillofacial and oral surgery, and prosthodontics. In the present literature review, we have discussed the different clinical applications of various 3D printing technologies in dentistry. Evidence indicates that 3D printing approaches are usually associated with favorable outcomes based on the continuous development and production of novel approaches, enabling clinicians to develop complex equipment in different clinical and surgical aspects. Developing work models to facilitate diagnostic and surgical settings is the commonest application of these modalities in dentistry. Besides, they can also be used to manufacture various implantable devices. Accordingly, they significantly help enhance the treatment process, reducing costs and less invasive procedures with favorable outcomes. Finally, 3D printing technologies can design complex devices in a facilitated and more accurate way than conventional methods. Therefore, 3D printing should be encouraged in clinical settings for its various advantages over conventional maneuvers.

Keywords: 3D printing, Dentistry, Clinical application, Efficacy

INTRODUCTION

Evidence shows that the 1st 3D printing technology was introduced in 1986. After which, many advances were reported in multiple fields with multiple clinical applications.[1,2] In this context, Huller created and developed a 3D printing system was created and developed in 1986 Huller, which also printed stereolithography (SLA). Moreover, fused deposition modeling (FDM) was first introduced by Scott Crump in 1990.[3] Since these advances, many technological breakthroughs have been reported for 3D printing technologies.

3D printing can be used to develop personalized 3D subjects according to computer-aided design (CAD) digital approaches via particular automatic processes and standardized materials.[4-6] Many applications for these technologies have been reported within the last three decades in multiple fields, like manufacturing, engineering, design, and industry. In addition, it has also been used in various medical fields, like craniomaxillofacial surgery, plastic surgery, neurosurgery, cardiology, traumatology, patient-physician communication, customizing surgical devices, and digital imaging in surgical planning.[7] Furthermore, many applications have also been reported in the field of dentistry, including periodontology, endodontics, orthodontics, oral implantology, maxillofacial and oral surgery, and prosthodontics.[8,9] In the present literature review, we will discuss the various clinical applications of 3D printing technologies in dentistry based on the results and outcomes of previous relevant studies.

METHODS

This literature review is based on an extensive literature search in Medline, Cochrane, and EMBASE databases on which was performed 03 December 2021 using the medical subject headings (MeSH) or a combination of all possible related terms, according to the database. To avoid missing poetential studies, a further manual search for papers was done through Google Scholar, while the reference lists of the initially included papers. Studies discussing application of 3D printing and its various technologies in dentistry were screened for useful information, with no limitations posed on date, language, age of participants, or publication type.

DISCUSSION

Among the various investigations in the literature, it has been shown that different clinical applications have been proposed for 3D techniques. In the present section, we will discuss these applications based on data from relevant studies in the literature. However, the commonest applications for 3D printing technologies appear to be used for surgical treatment and diagnostic purposes. Besides, it has been shown that these technologies can be furtherly used in different fields, including oral implantology, maxillofacial surgery, prosthodontics, and others.

For instance, it has been demonstrated that 3D technologies can be effectively used in prosthodontics to scan, prepare, and print teeth immediately in one session during the clinical setting. Accordingly, these technologies can effectively save time and cost.[10] In addition, clinicians can effectively prepare optimal teeth models by using extraoral or intraoral scanners. CAD software can be used to achieve favorable restorations and treatment outcomes. It has been shown that these applications can be used to print various dental restorations.[11] In this context, evidence indicates that resin-based 3D technologies (including DLP and SLA) can be effectively used to fabricate crown and bridge dentures.[12,13] A previous study reported that the main advantage of using these technologies is minimal loss of materials and the number of materials used compared with milling.[14] These modalities can also obtain favorable detail reproducibility when aiming to print various materials simultaneously. A previous investigation by Wang et al. [15] evaluated the authentic actuality of milled crowns and 3D printing crowns and found that the external trueness of both modalities was remarkably similar. A good fit is recommended when planning for the treatment strategy to maintain the surrounding tissues' health, durability, and mechanical stability.[10] If the materials were not adequately fit, various adverse events could develop in this context. These include the development of periodontal diseases, dental caries, tooth sensitivity, lack of esthetics, discoloration, microleakage of adhesive, and dental plaque accumulation over the edges.[16]

Many studies demonstrated that the application of 3D-based temporary crowns significantly achieved enhanced internal fit abilities and excellent edges. These effects were more significant than those obtained when applying temporary crowns manufactured by traditional milling approaches and CAD/computer-aided manufacturing.[17] This has been further indicated in a previous investigation by Pomba et al which compared the differences between 3D printing, molding, and milling methods regarding internal fit and edges of fabricated temporary crowns.[18] The most favorable events were associated with the molding method followed by 3D printing, which might be attributed to volume shrinkage during polymerization. Other studies even reported that the differences were even greater when it was aggregated within a single piece.[18] Another study by Chaturvedi et al further reported that 3D printing was significantly associated with enhanced coordination of interior, edge, and proximal ends of the temporarily fabricated crowns.[11] On the other hand, another study by Alharbi et al concluded that the internal clearance values and edges were remarkably lower for 3D printing than milled restorations.[5] However, this has been attributed to the errors associated with milling tool tolerances.[19,20]

Evidence indicates that 3D printing techniques can also fabricate complete resin-based dentures with reduced need for tooling fixtures, cutting tools, or molds. It has been furtherly shown that other modalities rather than 3D printing technologies (like traditional curing with heat, subtraction technology, and self-curing modalities) might additionally be applied in fabricating complete denture bases.[21] Studies also showed that combining compression molding technology and polymethylmethacrylate is common. However, these studies showed that these modalities' linear shrinkage and volume are higher than 3D printing techniques.[22] On the other hand, 3D printing technologies are usually associated with a reduced frequency of errors secondary to reduced working stages and faster production of dentures.[23] However, evidence shows that applying these modalities in this field is still under investigation. It should be noted that adequate tissue adaptation is vital for the stability of removable dentures, performance retention, and masticatory.[24] In this context, a previous study by Tasaka et al concluded that photopolymerization spray was significantly able to fabricate complete denture bases that are more accurate than the ones obtained by conventional thermal polymerization.[25]

Using 3D printing was also efficiently reported in obtaining removable partial denture frameworks. Various investigations in the literature also indicate that the modality is usually associated with more favorable outcomes than conventional approaches. For instance, it has been shown that these conventional modalities are usually associated with poor casting fit more significantly than 3D printing approaches.[26] Besides, studies also reported that the associated clinical complications are mainly attributed to residual ridge resorption and pressure-induced mucosal lesions. In this context, evidence indicates that 3D printing techniques significantly reduce the risk of long-term bone resorption and provide an enhanced and uniform contact pressure. A previous investigation reported that SLM obtained clinically-acceptable removable partial dentures.[27] Another study by Tregerman et al showed that enhanced mechanical and organization characteristics were more significant with SLM Co-Cr alloys than milled or cast removable partial dentures.[28]

There is also evidence of the efficacy of applying 3D printing technologies and CAD/CAM technologies in conducting efficacious maxillofacial and oral surgeries. Many advantages have been reported for using these modalities in maxillofacial surgeries. For instance, it has been demonstrated that they can significantly enhance the functional impacts and symmetry of maxillofacial and oral surgeries and the associated techniques.[29] On the other hand, some studies reported that milling approaches for manufacturing the occlusal splints might be associated with a remarkable waste in materials and time-consuming. Besides, the process can be associated with filling errors that can also reduce the efficiency of these modalities and limit their therapeutic efficacies.[30] On the other hand, when using 3D printing technologies, evidence shows that clinicians can manufacture several splints simultaneously. Accordingly, it has been reported that this is usually associated with favorable therapeutic outcomes, in addition to being time and cost-saving.[31] Unfortunately, many previous investigations have reported that 3D printing materials do not usually have antiaging and antistress features similar to those with milling resin and traditional materials.[32] Accordingly, there have many concerns about the long-term efficacy of these modalities. A previous study by Lutz et al compared the efficacy of traditionally made, milled, and 3D printed occlusal splints.[33] The authors reported that flexure resistance and wear were significantly lower in 3D printed appliances than other approaches. Besides, it has been shown that these materials can be effectively used with a remarkable clinical efficacy for one month.[33] However, it should be noted that the accuracy and milling and 3D printed splint are similar.[34] It should be noted that the differences in materials and technologies can significantly impact the occlusal splints' performance. Evidence also indicates the efficacy of 3D printing technologies in surgical implants. Studies showed that reconstruction and manufacturing of customized porous implants, as customized Ti mesh, can be effectively done by direct beam melting and laser sintering.[35] A previous study further demonstrated that SLS technologies successfully manufactured bone conductive and completely biodegradable nanocomposite scaffold mechanical characteristics and adjustable porosity.[36] In a previous study by Farré-Guasch et al, the authors reported that laser sintering technologies could successfully induce mandible formation.[36] A new customized bone was also implanted for a patient with facial deformities by an inkjet printer using an α-tricalcium phosphate powder.

Different studies in the literature explored the efficacy of 3D printing modalities in dental implantology and their abilities to manufacture accurate and digital models that are more efficacious than the traditional ones. Accordingly, many benefits can be obtained from applying these modalities. For instance, the efficiency of dentists can be significantly enhanced, the technical risk and technical difficulty can also be remarkably reduced, and the medical treatment process can furtherly be simplified and optimized. In addition, 3D printing techniques can be effectively used in the laboratory to manufacture static surgery guides or SLA guides, usually done by inducing perforations in jaw models. Moreover, previous studies indicate that the static surgical guide does not move during operations, which differs from the dynamic surgical guide.

Long-term stabilization of soft and hard tissues around dentures, achieving good esthetic effects, and simplifying the process of denture restoration can be achieved by the placement of an optimal dental implant.[37] On the other hand, studies show that the prosthesis's reduced long-term predictability and success rates can result from improper dental implant placement.[38] Accordingly, it is important to optimize the accuracy of surgical guides. A previous investigation also demonstrated that static-guided surgeries had less correlation error than real-time navigation.[39] On the other hand, another study by Jung et al reported no significant difference between the two approaches.[40] Another in vitro study by Tahmaseb et al compared the accuracy of conventional surgical guides with SLA guides.[41] It has been shown that the average deviation at the vertex and entrance was 2.1 mm and 1.5 mm, and 1.0 mm and 0.9 mm for traditional surgical guides and SLA guides, respectively.[42] Accordingly, it has been concluded that SLA guides had better accuracy than traditional surgical guides. Recent advances in 3D printing were also reported in obtaining successful custom trays. Many studies have reported that these modalities have simpler personalization and programming and reduced processing durations. It has been furtherly reported that 3D printing modalities can adequately complete all the production processes.[43] Therefore, they can be used for completely edentulous patients to make the workflow of direct implant-supported dentures simpler. A previous study compared the efficacy and accuracy of 3D printing modalities and traditional hand-made custom trays and reported that 3D printing technologies had better accuracy. In this context, many advantages have been proposed for 3D printed custom trays, including greater clinical satisfaction, high precision, and personalization than traditional custom trays.[44-47] Accordingly, these advantages allow for 3D printing technologies to be widely used in this field with favorable outcomes. Future implications should also encourage the clinical application of these modalities.[48-50]

CONCLUSION

Evidence indicates that 3D printing approaches are usually associated with favorable outcomes based on the continuous development and production of novel approaches, enabling clinicians to develop complex equipment in different clinical and surgical aspects. Developing work models to facilitate diagnostic and surgical settings is the commonest application of these modalities in dentistry. Besides, they can also be used to manufacture various implantable devices. Accordingly, they significantly help enhance the treatment process, reducing costs and less invasive procedures with favorable outcomes. Finally, 3D printing technologies can design complex devices in a facilitated and more accurate way than conventional methods. Therefore, using 3D printing should be encouraged in clinical settings for its various advantages over conventional maneuvers.

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