Digital Dentistry in Operative Dentistry: Literature Review

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Abstract

Digital dentistry is defined as the application of a digital or computer-related technique in the field of dentistry by which other modalities including the electrical, and mechanical can be dispensed with. It has been reported as an effective modality in impressions and recording, digital fixed prosthodontics, digital removable prosthodontics, implants-guided planning and surgeries, implants and prosthetic restoration, maxillofacial prosthetics, facial scanning, and shade matching. In this review, we aimed to discuss digital dentistry in the field of operative dentistry and discuss the recent updates in the field. According to the reviewed studies, digital implants can be used to reduce deviation and obtain better outcomes. Although this was a controversial point, we believe that the reported clinical outcomes are still significant and should be considered by clinicians. Moreover, it has been reported that the operator experience might be a crucial factor in obtaining the sought outcomes. Digital approaches have been also used in the field of fixed and removable prosthodontics with favorable outcomes and const-effectiveness. In maxillo-facial surgeries, digital dentistry has been also effective in designing suitable prosthetics which may be then used for fabrication to compensate for the defect.

Keywords: *Computer-Aided Design; Computer-Aided Manufacturing; Dental Impression; Dental Practice; Accuracy; Digital Dentistry*

Introduction

Digital dentistry is defined as the application of a digital or computer-related technique in the field of dentistry by which other modalities including the electrical, and mechanical can be dispensed with. Digital techniques have now been widely used in many fields including medical and non-medical ones. Such techniques are used in medical profiling, diagnosis, treatment modalities, database construction, drug designing, and food inspection [1,2]. In dental practices, it has been widely accepted that digital dentistry has affected this field and has become an essential factor in the diagnosis and management of many disorders especially these related to the prosthodontics approaches. The field of dentistry has witnessed many changes and advancements in the applied techniques that are used for diagnosis and

management [3,4]. At first, tools made out of wood were the first primitive techniques that have evolved until the development of digital techniques and their derivatives in the field, nowadays [5-7].

Various applications of digital dentistry have been introduced through previously published investigations. These applications are variable including the diagnostic, therapeutic, and laboratory approaches. Ahmed., *et al*. [8] used digital dentistry in a one-year follow-up study to evaluate the ability of this technique in diagnosing tooth wear progression. Additionally, many investigations have reported the use of this modality in impressioning and recording [9-11], digital fixed prosthodontics [12-14], digital removable prosthodontics [15-17], implants-guided planning and surgeries [18-20], implants and prosthetic restoration [21-23], maxillofacial prosthetics [24-26], facial scanning [27] and shade matching [28-30]. Digital technology has proven efficient in many of these fields and is now regarded as a convenient alternative to conventional modalities which allowed for computer-aided design/computer-aided manufacturing (CAD/CAM) modalities to be applied in the field [5,31-33]. Such techniques have been progressively updated to maintain a better quality of the intended clinical outcomes [7,34-36].

The accuracy of digital dentistry, however, is still of concern and the purpose of many recent investigations. It is known as the degree of deviation that occurs between the planned and achieved outcomes [37]. Moreover, the absolute use of digital dentistry over the conventional approaches is still controversial as some clinicians prefer it while others do not [38]. Besides, a variety of study designs including clinical, cadaver and *in vitro* designs could be identified in the literature which may influence the accuracy results [39]. In this report, we aim to discuss digital-dentistry related studies in the fields related to operative dentistry.

Methods

We performed an extensive literature search of the Medline, Cochrane, and EMBASE databases on 27th October 2020 using the medical subject headings (MeSH) or a combination of all possible related terms. Papers discussing the digital applications in the fields related to operative dentistry were screened for relevant information. We did not pose any limits on date, language, age of participants or publication type.

Digital implants-guided planning and surgery

Many useful and creative techniques have been proposed to serve as dental therapeutic modalities as a result of combining virtual engineering into the field of dentistry. Using digital surface scanners together with surgical planning software has provided for the use of a combined prosthetic, radiographic, surgical, and laboratory approaches into one operation to get a better quality of diagnosis and treatment. Many studies have been published in the field of digital-implants where authors have reported efficacious digital modalities in this field. Lanis., *et al*. [20] reported a successful surgery after using a combination of cone-beam CT with a digital surface scanner to perform an implantation surgery using a studio software of a 3-shape implant model. Andrade., *et al*. [19] compared between 64-Detector-Multislice and Cone Beam CT and their ability to evaluate linear measurements in the alveolar ridge. The authors reported that no statistical significance was found between the two modalities on the sought outcomes. The efficacy of this modality might be dependant on many factors as the experience of the individuals conducting the surgery. Similarly, Nejad., *et al*. [40] used the cone-beam CT to fabricate a guide for the all-on-4 surgery where no flap reflection was approached. The authors described that this protocol allowed for implant placement to be duplicated clinically following successful laboratory modeling. Despite not being widely-used, high-quality desktop 3-dimensional stereolithographic printers have been also reported to obtain better outcomes at lower costs [41]. Xu., *et al*. [18] applied cone-beam CT to scan a stereolithographic implant model, and the results were matched between the virtual and actual implant positions. The authors reported that a significant deviation was caused by the surgical template between the actual and planned implant outcomes. Similar values were reported by similar studies also. A mean of 1.45 mm at the hex was reported by Giacomo., *et al*. [42], another of 1.47 mm by Cassetta., *et al*. [43] and a mean of 1.28 mm by Ozan., *et al*. [44], while Pattersson., *et al*. [45] and Dreiseidler., *et al*. [46] reported mean horizontal errors of 0.8 mm and 0.2 mm, respectively. While horizontal deviation at the apex was 2.99 mm in Giacomo., *et al*. [42], another of 1.83

mm by Cassetta., *et al*. [43] and a mean of 1.57 mm by Ozan., *et al*. [44], while Pattersson., *et al*. [45] and Dreiseidler., *et al*. [46] reported mean horizontal errors of 1.9 mm and 0.3 mm, respectively. A systematic review was conducted by Schneider., *et al*. [47] to evaluate the clinical outcomes and accuracy of CT-guided template-based implant dentistry. A total of 10 articles investigating the clinical outcomes were included while a total of 8 investigated the accuracy. The authors reported that the survival rates of the implants were found to be 91 - 100% after a 12 - 60 months follow-up period with a 9.1%, 18.8%, and 12% rate regarding the early surgical complications, early prosthetic complications, and late prosthetic complications, respectively, among the included patients of the analyzed studies. Moreover, the results showed that the mean deviation at the apex and hex was 1.63 mm (95% CI: 1.26 - 2), and 1.07 mm (95% CI: 0.76 - 1.22), respectively, while a mean vertical error of 0.43 mm (95% CI: 0.12 - 0.74) was estimated. This usually happens as a result of the inadequate experience of the operator, improper placement of the template on the patient, inaccurate interpolation of the softwre results, or due to obtaining the results of the CT scans. Causes behind error in implant positioning can be subdivided into error on the designed surgical template, and errors achieved by the operator. Both of these concepts can lead to a final deviation of the implant from its planned site, and can be inconvient in fitting the patient. Previous studies reported that operator experience was a key factor in increasing implant survival [48-51]. These studies showed that the more experience that the operator has, the more accurate implantation would be installed. On the other hand, Rungcharassaeng., *et al*. [52] investigated evaluating the effect of the operator on the accuracy of performing one dental implant using a computer-guided surgery. The authors reported that no statistical significance was noticed among the experienced and non-experienced participants, however, experienced personnel could obtain better results regarding a less vertical deviation in the dental coronal direction.

Digitized dentistry for fixed and removable prosthodontics

Studies in the literature indicate that digital impression systems are the best modalities in obtaining accurate marginal ceramic restorations. On the other hand, other studies show that conventional impression is better than full-digital fabrication in obtaining more better outcomes, therefore, the results from these studies are still controversial. Gherlone., *et al*. [53] conducted a 3-year retrospective investigation to assess the ability of fabrication-based digital impressions in maintaining the survival of zirconia-based single crowns in their population. The authors reported that none of the crowns were lost at the end of the 3-months follow-up period, however, an increase in the chipping rate of the veneering material was at the same point was found to be 30.2%, and therefore, the real success rate for this digital-based method was estimated to be 69.8%. The authors justified the reduction in the success rate by the fatigue-mechanism which may have contributed to the increase in the chipping rate, especially after the second year. Mostafa., *et al*. [54] compared digital impression and manufacturing, the digital impression in addition to traditional pressed manufacturing, and traditional impression in addition to manufacturing in the restoration-based fabrication of the marginal fit of lithium disilicate crowns. The authors reported that all crowns in the digital impression and manufacturing were acceptable and that digital impression and CAD/CAM are better alternatives than the conventional modalities in achieving better outcomes. In 2013, a systematic review of 54 studies including 48 *in vitro* and 6 *in vivo* studies that aimed to test ceramic systems was conducted by Contrepois., *et al* [14]. The authors concluded that using computer x-ray microtomography was found to be significant in obtaining better marginal fit outcomes. On the other hand, in 2016, a meta-analysis by Tsirogiannis., *et al*. [55] analyzed the results of 12 investigations that compared conventional and digital impressions in obtaining an enhanced marginal fit. The results indicated that no significant difference was noticed in the marginal discrepancy between the two modalities. A randomized controlled trial by Benic., *et al*. [56] in 2016 compared conventional impressions and different modalities of digital impression. The authors reported that conventional impression was supreior to the approached digital impression sytems in terms of time-effectiveness, but not in patient comfort terms, where no modality was deemed superior to the other. Moreover, other favorable outcomes with some of the digital approaches were equal to those with the conventional impression. Therefore, it could be concluded that digital impressions should be carefully used and further studies are needed for further validation. In 2018, a systematic review by Ahlholm., *et al*. [57] reviewed the results of previous studies in the literature that compared digital and conventional impressions. The results showed that digital impressions were time-effective, and although they are considered acceptable, conventional impressions are still recommended as the first-line modalities.

Many previous studies have also investigated the application of digitalized dentistry in the installment of removable prosthodontics. Different forms of dental restorations as crowns, partial crowns, dental veneers and inlays, and fixed partial dentures (FPDs) have been previously developed using CAD/CAM modalities. The application of such modalities can save many efforts and are cost-effective, however, they are not absolutely validated due to the controversial advantages over the controversial modalities. Moreover, efforts have been made to introduce more accurate digital software that can be used for the fabrication of complete dentures. Li., *et al*. [58] developed the 3Shape Dental System 2012 that is mainly based on combining single coping and full anatomical FPD to obtain complete dentures designs. Ye., *et al*. [24] investigated the validity of CAD in addition to rapid prototyping techniques in obtaining removable partial denture (RPD) and in achieving desired outcomes for clinical application. The results of the study showed that CAD with the rapid prototyping techniques was significantly efficient in obtaining acceptable clinical outcomes and can be used for the fabrication of RPD frameworks. A pilot clinical study by Schwindling., *et al*. [59] compared two digital approaches for fabricating complete removable dental prostheses in five patients, for whom two types of digital modalities were designed. The authors reported that both of the designed techniques were able to achieve acceptable clinical outcomes with no major complications. However, due to the small number of the included participants, the authors called for further validation by future studies with bigger sample sizes. In the same context, Bidra., *et al*. [16] conducted a systematic review for investigating the efficacy of CAD/CAM in fabricating complete dentures. The authors reported that according to eight articles included, the results showed that CAD were deemed effective in obtaining complete dentures, however, no randomized controlled trials were published in this field, so the evidence might not be absolute.

Digitized dentistry for maxillofacial prosthetics

Previous reports investigated digital approaches trying to enhance the field of maxillofacial prosthetics surgeries and find the most convenient modalities for these patients. Grant., *et al*. [60] showed that digitally-obtained maxillofacial prosthetics might be the convenient solution in pediatric patients where full-cooperation and appropriate designs cannot be obtained by the conventional modalities. Rodney., *et al*. [25] used a 3D printer for the fabrication of their surgical obturator that was previously designed by an animation software that was mainly dependant on data from CT of the patient. The results showed that the process was effective in achieving the successful obturation of the maxillectomy disorder. In general, 3D printing is now an acceptable modality in the field of operative dentistry. The different aspects of this modality have been previously reviewed by Dawood., *et al* [61]. Another review made by Memon., *et al*. [62] concluded that digital-based maxillofacial implants are promising techniques, and are cost-effective, however, some concerns should be taken into consideration including the accuracy of the used software. The authors showed that continuous upgrading of the used softwares will be the righteous approach for enhancing the accuracyof such modalities, however, it is time consuming. Moreover, future studies are needed to simplify these projects and make them user-friendly and cost-effective.

Conclusion

Digital techniques are now widely used in the field of dentistry with previous evidence of acceptable success rates in the different approaches they are being used for. Previous studies showed that digital implants can be used to reduce deviation and obtain better outcomes. Although this was a controversial point, we believe that the reported clinical outcomes are still significant and should be considered by clinicians. Moreover, it has been reported that the operator experience might be a crucial factor in obtaining the sought outcomes. Digital approaches have been also used in the field of fixed and removable prosthodontics with favorable outcomes and cost-effectiveness. In maxillo-facial surgeries, digital dentistry has been also effective in designing suitable prosthetics which may be then used for fabrication to compensate for the defect. This does not exclude the need for future population-based studies especially the randomized controlled trials for further validation of the modalities' accuracy.

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