Three Dimensional Digitally Designed Surgical Guides in Periodontal and Implant Surgeries: A Review

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Abstract
The development of technology in all fields resulted in replacing old and conventional strategies with a more comfortable and efficient strategy. The three-dimensional digital surgical guide is a more recent technology used for diagnosis and treatment planning for a complex implant-supported prosthesis. An electronic research process was used from 2010-2019 using PubMed, Science Direct, and Google Scholar to obtain the articles. A three-dimensional digital guide in surgical implant placement, esthetic crown lengthening, bone regeneration, and titanium mesh showed promising results.

Keywords: 3D surgical guide, CBCT, CAD/CAM, Dental implant

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1. Introduction
Planning of implant prosthesis should begin much time before surgical implant insertion [1]. Implants placement has been planned and facilitated for years utilizing simple panoramic radiographs [2]. Surgical techniques achieve more precise implant placement at the surgical site [3,4]. A surgical guide helps diagnose, plan, and treat and facilitate proper positioning and angulation of bone implants [5]. Tooth supported surgical guides accuracy of implant placement is superior to that with bone and mucosa supported guides [6,7]. There are several advantages for guided implant surgery, including helping the dentist perform less discomfort flapless implant surgery, faster working and healing time, more predictable manner, and safer placing of implants [8,9]. Conventional surgical guides are two-dimensional imaging and guide made on the dental cast; this conventional technique was used for assisting in proper surgical placement [10]. Traditional surgical guides are made in dental laboratories. They allow for clinician-mediated positioning errors due to the linear deviation and inadvertent angular, leading to a reduction in accuracy [11].

Digital flow work has an essential role in contemporary dentistry [12]. Recently, both digital scanning and cone-beam computer tomography (CBCT) are used to plan guided implant surgery and digital workflow [13,14]. Three-dimensional imaging techniques can add an additional dimension to routinely available preoperative radiographs [15]. This review aims to overview the using a three-dimensional digital guide in surgical implant placement, esthetic crown lengthening and bone regeneration, and titanium mesh.

2. Methods
An electronic research method was used to search for studies related to three-dimensional digitally designed surgical guides in periodontal and implant surgeries. Scientific websites such as PubMed, Science Direct, and Google Scholar were used to obtain the articles. The research review was conducted from January 2010 to February 2020 for English language articles published in the dental literature, using the keywords such as “CAD/CAM, 3D, Digital workflow, Guided bone regeneration, Titanium mesh”. Thirty-four studies were obtained, 15 articles were included in this review, and the other articles were excluded.

3. Three Dimensional Techniques
They can help provide more details regarding bone quality, volume, and anatomical restrictions [16]. Data obtained from CBCT, MRI, or CT can be processed in implant software and review preoperative views of anatomical structures related to a scanning template used for future restoration [17]. Imaging modalities with a three-dimensional vision of the tooth and surroundings is fundamental for better diagnosis and future dentistry planning [18]. The development of radiographic technology led to the introducing various three-dimensional imaging systems in the dental profession [18].

CBCT created a revolution in the dentistry field. It is dedicated to providing 3D images of oral structures and dental surroundings by expanding the role of 3D dental images from diagnosis to image guidance of surgical
procedures [18]. CBCT allows the acquisition of rapid volumetric images taken in time at different points similar in contrast and geometry, making it possible to evaluate variations occurring in the fourth dimension [18]. It was demonstrated that the CBCT scan provided the potential for improved patients' diagnosis, and it has a great range of clinical applications [18]. The three-dimensional radiological display is frequently indicated for treatment planning of complex implant-supported prosthetic restoration and diagnosis of bone pathology; further indications include diagnosis of the maxillary sinus [18].

Computer-aided design/computer-aided manufacturing (CAD/CAM) permits the production of surgical guides that are virtually designed and planned using data from 3D imaging by using computer software and digital workflow for manufacturing and planning [10].

4. Using Three Dimensional Digital Guide in Surgical Implant Placement

Dental implants became the treatment option for restoring missing teeth. Replacing missing teeth with implants has a major influence on the life of patients; this treatment is used by partially and completely edentulous patients [19]. The implant's success is based not only on osseointegration but also on implant placement, allowing fabrication of prosthesis or crown with esthetic appearance [20]. In implant dentistry, proper placement is one of the most critical factors [21,22].

3D CBCT is required for implant procedure in several steps; some anatomic considerations should be known to allow the clinician to determine the best site for the implant that will meet the prosthetic goals. In addition, 3D CBCT used to determine bone dimensions (height and width), bone quality and comparative density, determining the long axis of alveolar bone, localization and identification of internal anatomies including sinus cavities and nerves, determination of boundaries of the jaw, using 3D scale and scope or identifying pathology, transferring of radiographic planning information and binding planning information with radiographic diagnostic [23]. Of all the previous considerations and steps, a 3D strategy was required for three steps.

One study compared the accuracy of implant placement using 3D printing and machine milled surgical guides; it was found that both 3D printing guides and machine milling can be used in manufacturing surgical guides. However, 3D printing provided better results over machine milling [10]. In a review article [18], it was demonstrated that in case of the placement of an implant invades the sinus, approaches a nerve, or penetrates out of the confines of the jawbone, CBCT 3D imaging should be offered and discussed with the patient, and the patient should be aware of benefits, risks and alternative treatment [18]. It was reported that a fully digital workflow using CBCT for digital planning implant placement and application of fixed implant-supported prosthetic restoration was reliable [12].

Another study investigated the benefit of full three-dimensional virtual work to guide the placement of an implant in oligodontia. The study showed that using computer-designed surgical templates helped predict implant placement, where interdental spaces were limited, and the patient's bone was scarce [24].

In a case report of a patient with missing mandibular right first molar who underwent rehabilitation with dental implant-supported prosthesis, 3D CBCT, and virtual cast were used in dental implant placement planning, and this results in less pain and discomfort experienced by the patient, the procedures consume less time compared to the conventional procedure. The authors suggested that 3D guided implant surgery is expected to be a routine procedure for rehabilitation [25].

A clinical report on a 73 years old male patient who experienced mandible and maxilla rehabilitation with implants and implant-supported prostheses using digital workflow showed that this technique predictably allowed esthetic and functional rehabilitation and integrated with the face of the patient [26].

5. Three Dimensional Esthetic Crown Lengthening Guide

One of the dental practice parts is esthetics, which results in a good smile; this depends on the architecture of the gingival tissue and dental characteristics. An interdisciplinary approach between periodontists and prosthodontists is required to achieve successful esthetic rehabilitation for the short clinical crown and excessive gingival display [27]. Esthetic consideration is the first step in the treatment plan for the maxillary anterior region [28]. In the case of crown lengthening is needed to be performed, the surgeon should receive all information on optimal gingival contours and tooth esthetics when. Diagnostic waxing was suggested to generate a vacuum-formed surgical guide and an acrylic resin [29,30,31]. However, these devices are not precise in most times [32]. A distance of 3 mm between the gingival margin and alveolar crest on the facial aspect is essential for periodontal health, allowing for 1 mm and 2 mm of sulcus depth and biological width, respectively [33]. The amount of alveolar bone needed to be removed can be anticipated; however, the lack of a guide for bone resection may lead to undesirable post-treatment esthetics. CAD/CAM techniques helped surgeons perform predictable, accurate surgery, and improved esthetics outcomes [34]. This technique references bone and gingival restoration during crown lengthening surgery; this technique increases treatment predictability and facilitates the surgical procedure. This digital approach results in pleasing esthetics and harmonious gingival and alveolar contours [34]. The present clinical procedure is superior to the conventional one as it encouraging a harmonious correlation between gingival and teeth, provides more predictable alveolar and gingival margins, and allows fewer surgical errors. Limitations of such a technique involve increased cost and additional time required before surgery [34]. There are only 2 case reports discussed digital techniques. One case report [35] was conducted to present the virtual planning used as an aid in periodontal surgical planning to correct the gummy smile. The authors reported that the digital smile design technique was found to be versatile and can be used for planning periodontal surgery. Another case report [36]
showed that using three-dimensional printing templates and CAD/CAM techniques can guide clinicians in patients who require rebuilding an ideal contour in the esthetic zone for the marginal gingiva anterior maxillary.

If the patient requires esthetic crown lengthening surgery from the right maxillary lateral to the left central incisors to treat excessive gingival display and crowns on the maxillary central incisors to correct defective existing restoration, then the following technique will be used as following [34];

a- An intraoral scanner (TRIOS; 3Shape) can be used for intraoral digital impressions that should be considered for mandible, maxilla, and maximal intercuspal position. Scanning of mandible and maxilla is performed in the semi-open mouth using cone-beam computed tomography (CBCT). The digital impressions should be saved as a "3ox" file, and you can save them in a file named File A, whereas the CBCT file can be saved as File B.

b-2dimensional clinical photography should be used to design the teeth shape and gingival contour, which is performed according to the facial treatment plan. From this, a clear image of the planned esthetic restoration for the prosthodontists and periodontists can be obtained by designing virtual restorations on a three-dimensional digital model named File A.

c-For designing a gingivectomy guide, the tooth geometrical shape and gingival margin on file A should be drawn and then printed using a digital dental printer.

d-A digital software " sigma dental CAD" uses files A, D, and virtual restoration. The two files should be merged using the best-fit algorithm by registering the clinical crowns into a single digital file, which can be saved as file C. The dental technician can notice the correlation between the virtual gingival margin and alveolar bone on the merged digital model. Drawing of the potential alveolar crest that is 3mm away from the potential gingival margin should be done. Then, the alveolectomy guide should be designed on which the open window exposes the alveolar bone to be removed and print.

e-Making of an internal bevel incision based on the gingivectomy guide and removal of collar tissue should be done. Then, reflect the full thickness flap on the labial side to expose the alveolar bone, leaving the papilla in its original site. The excess bone should be removed through the windows in the alveolectomy guide; this is followed by reposition and suturing the flap.

f-The soft and hard tissue becomes mature after three months of surgery, so restore the central incisors, which ceramic crowns.

6. Three Dimensional Techniques Used in Titanium Mesh

Both floor and orbital wall are common sites of facial bone fracture, leading to serious functional impairment [37]. The treatment of such fractures is difficult as this anatomical region is complex, and hence the intra-operative view is limited. Both clinical examination and meticulous imaging are indispensable for treatment planning. Visual anesthetic and disturbance can result from inaccurate surgical techniques and unfitted implants [38]. In order to achieve adequate post-operative results and stable reconstruction, individual titanium mesh implants and computer-assisted three-dimensional treatment planning are applied [39,40].

New standardized titanium mesh is manually adjusted to fit polyanide models of each patient [41]. Titanium mesh was introduced to eliminate or limit some problems such as lack of containment of the particulate graft, so they are used as a containment system for the particulate autogenous and alloplastic grafts when augmenting the atrophic mandible and maxilla [42]. The use of conventional titanium mesh was explained for the first time to reconstruct osseous-maxillofacial defects and then used for the osseous restoration of deficient edentulous maxillary ridges [43,44,45]. They are also used for limited alveolar ridge augmentation of ridge defects with simultaneous and secondary implant insertion [46,47,48]. CAD/CAM technology provides satisfactory solutions for time-consuming and manually challenging disadvantages of premade TM based on the CBCT scan data of the bony defect and digital workflow system [49]. One study [50] reported titanium implants suitable for daily use. These patient-specific implants (PSI) allow more time and cost-effective operative procedures. It also allows precise reconstruction of orbital fractures by using complete digital workflow, and they advised to be superior to the implant's malposition. Another study described a protocol for manufacturing individualized direct laser-sintered titanium mesh using CAD/CAM procedures and rapid prototyping. The manufactured titanium mesh can be used for bone regeneration [42].

7. Three Dimensional Techniques Used in Bone Regeneration and Titanium Mesh

Dental implant placement is a practical plan for treating lost teeth; this plan presents high survival rates after a long term of follow-up [51,52,53]. However, such implants' long-term stability and success depend on the quantity and quality of the bone available at the post-operative implant site [54,55]. Several augmentation procedures were described and were studied in animals and humans [56]. Guided bone regeneration is a therapeutic method that can be used in cases with insufficient alveolar bone width and high [57]. Autologous bone or bone compensatory are used to fill the bone defect, then covered with artificial membrane; this bone augmentation enhances implantation [58].

Clinical studies reported promising results for vertical and lateral bone reconstruction with a titanium mesh technique [59]. Customized titanium mesh cage can be manufactured to fit precisely over the bone defect of augmentation situ. However, the risk of flap dehiscence with the graft site's exposure and possibly some or complete loss of the graft material remains present due to the titanium mesh's stiffness and mechanical irritation to the mucosal flap [50,51]. One rapid prototyping method called selective laser melting (SLM) is a manufacturing process for the production of an implantable dental device [62,63,64], which facilitates the manufacturing of microstructures or even the finer structures [65,66]. The SLM technique is a developmental rapid prototyping process that automatically integrates successive laminae as
they are defined to form the desired 3D object [67]. One study reported a good and safe augmentation technique for combined and vertical defects [49]. Another study [67] overviewed the successful development of a novel protocol for guided bone generation using individualized made titanium devices. The study revealed that the novel protocol was safe and simple for providing robust support for guided bone regeneration.

8. Conclusion and Future Direction

Using a three-dimensional digital guide in surgical implant placement, esthetic crown lengthening, and bone regeneration, and titanium mesh showed promising results. With advanced technologies, the three-dimensional guide would be a promising tool for diagnosis and treatment planning in the future. However, the number of studies was limited studies on its role in customizing the titanium mesh in the guided bone generation, so further well-designed studies and reports are required for the three-dimensional surgical guide in dentistry.

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