A New Transfer Technique (San Technique) of CAD/MAM Surgical Guide for Prosthetic Driven Implant

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Abstract: ***Statement of problem****: there is absence of link between virtual implant planning and manually fabricated surgical guides. Purpose: to design and evaluate a simple technique (San technique) to manually fabricate cast-based surgical guide derived from virtual computer aided design.* ***Materials and methods****: Ten partially edentulous patients were selected for this study. The standard radiographic template were fabricated and a reference plate with three radiographic markers where attached to the occlusal surface. CBCT was acquired and virtual implant planning was performed using AccuGuide software. The virtual plan was transferred to the manually fabricated surgical guide using an innovative simple technique (San technique). The implant bed was prepared through the surgical guide utilizing UniGuide surgical kit and Bicon dental implant was installed. Post-operative CBCT was superimposed onto virtual planning to evaluate the transfer accuracy. Data were collected, tabulated and statistically analyzed.* ***Results****: There was no statistically significant difference between the virtually planned and placed implants using the innovative San technique. The mean global deviation at the coronal level was 0.52± 0.19, while at the apical level was 0.84± 0.25 and the angular deviation was 5.14± 1.31 degrees.* ***Conclusion****: San technique produced acceptable functioning surgical guides. It represents a reliable convenient alternative to CAD/CAM fabricated surgical guides.*

Keywords: virtual implant planning, dental implant, surgical guide, CAD/MAM.

1. Introduction

The main goal of implant placement in prosthodontics is to restore the missing tooth to its function and esthetic in relation to anatomic structures. The success of implant-supported restoration depends on the position of the implant in addition to the implant integration in the bone. Implant position may affect the esthetics and function of the restoration. Restoratively driven treatment combines the three-dimensional location of the prospective restoration to the necessary implant position. The planned position must be transferred accurately to surgical field for successful treatment [1].

A detailed collection of clinical and radiographical information with interdisciplinary communication of the planning will provide successful dental implants to restorative patients. Early, in the evolution of osseointegration surgery, dentists placed implants in where maximum bone volume was available, without consideration to the final position of the crown. Biomechanics, esthetics and maintenance were compromised. Implant planning recommended to be driven by prosthodontic, using a crown-to-bone concept. It takes into account the restorative requirements, followed by examining the bone to evaluate the possibility of implant installation [2].

An ideal restoration is expected after optimal implant placement. In this regard, three factors need to be considered: position, angulation and depth. Many implant placement issues are not diagnosed until the prosthetic phase of treatment, when an abutment is attached to the implant [3].

A surgical guide should be used as guidance in three planes (bucco-lingually, mesio-distally, and occluso-apically) for inserting implants in the proper position to prevent prosthetic complications [4]. In addition, the surgeon has to understand the required smooth transition from the surgical to the prosthetic phases of therapy [5].

The surgical guide was used only for implant bed preparation but in 2003, Tardieu, et al. developed a single surgical guide for both the drilling and implant placement. Which control the position, angulation, and the depth for accurate drilling and implant placement [6].

The ideal surgical guide should accurately translate diagnostic information from pre-surgical diagnostic wax-up and transfer them to the surgical site for correct implant placement with restoration in optimal functional occlusion [7]. The surgical guide must be stable and accessible when placed intraorally and also able to be sterilized [8].

The CAD/CAM implant dentistry connect the advantages of optimal 3D diagnosis and software-based planning by accurately transferring the virtual implant positions to the surgical sites in the patient’s mouth. The accurate transfer of implant planning are important for flapless surgery approaches, to prepare prosthesis prior to surgery for immediate loading, to reduce the risk of injuring critical

anatomical structures and to eliminate manual placement error. In addition each system has advantages, disadvantages, and potential sources of error [9].

There are many techniques involved in the construction of CAD/CAM surgical guide, all have the disadvantages of being expensive and needs specialized manufacturing center. This study evaluates a technique for cost-effective CAD assisted manually constructed surgical guide.

2. Materials and Methods

Ten short span partially edentulous patients with age ranging from 30 to 50 years were selected for this study. They were indicated to implant-borne prosthesis with a good oral hygiene and awareness. This study was approved by the ethics committee at Beirut Arab University (2015H-020-D-P-0062) and a written informed consent was obtained from each participant.

The maxillary and mandibular impression (Imprint™ II VPS) were made and poured, using extra hard stone (BonTop type IV) according to the manufacturer's instructions, with a P/L ratio of 100 g / 20 ml. The models were trimmed and each model was identified with the patient's information. The face-bow (UTS) was used for the skull/joint-related model orientation on a semi-adjustable articulator (Stratos® 200).

The GEO Snow White wax material was used for diagnostic wax-up of the intended restorative contours. The putty impression material was adapted to surround all the surfaces of the wax-up to construct model. After removal of wax-up a radiopaque chemically cured composite Protemp was injected into the silicon mold and repositioned over the model into the appropriate position. The resin tooth was properly trimmed and a 1 mm diameter hole was drilled in the axis of the resin tooth as shown in figure 1 [10].

Figure 1: The resin tooth with hole in the axis.

The resin tooth was repositioned, accurately fitted onto the model, and glued to the cast. The model was placed on the Discus* vacuum former platform with the teeth upright and vacuum form sheet was fabricated. Then, the vacuum-pressed material (including the radiopaque resin tooth) was trimmed, to as standard radiographic template [11] as in figure 2.

Figure 2: The standard radiographic template.

The radiographic template was repositioned on the model and attached by autopolymerizing acrylic resin to a radiographic reference plate using San mounting device (Figure 3). After that removed, trimmed to the proper contour, disinfected, fitted into patient mouth and referred for radiographic acquisition.

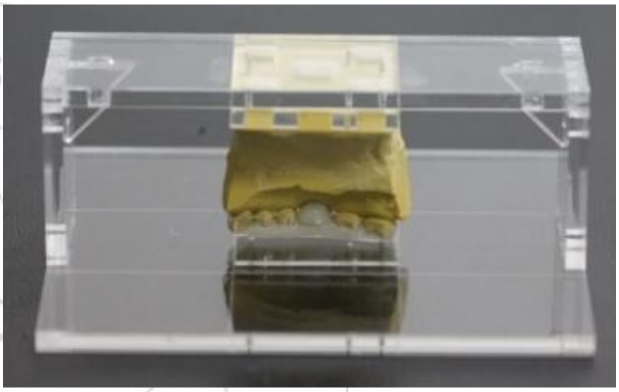

Figure 3: San mounting device.

Radiograph was acquired using KODAK 9000 3D CBCT machine with parameters were set to 70 KV, 8 mA, and 200 µm Voxel. After image acquisition, the CBCT images were reformatted by CS 3D imaging software and saved as DICOM files, as shown in figure 4.

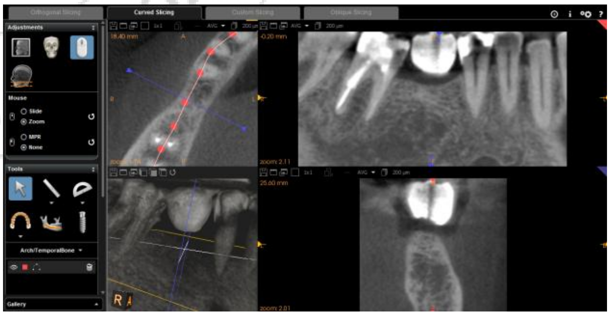

Figure 4: Reformatting and saving the DICOM file. The virtual planning was accomplished by using AccuGuide Software. The implant brand, model and size were selected and drawn in all views by the U-Plan module, as illustrated in figure 5.

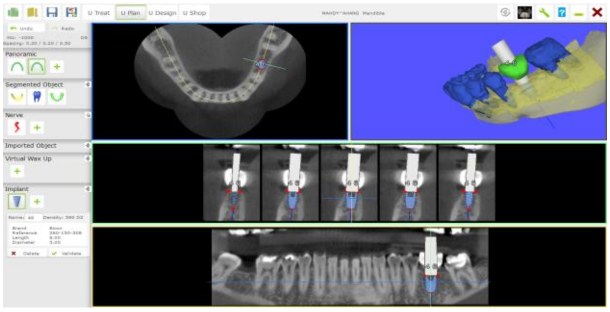

Figure 5: AccuGuide Software, the U-Plan module.

A screen capture that recorded the trajectories and the depth of virtual implant was recorded and printed on transparent verification sheet to be properly positioned on the monitor screen during aligning of guiding cylinder. The model was removed from San mounting device and properly positioned into the San device that was secured to the surveyor table. A prepared vacuum formed sheet of 2 mm thickness [12] was repositioned over the model as shown in figure 6.

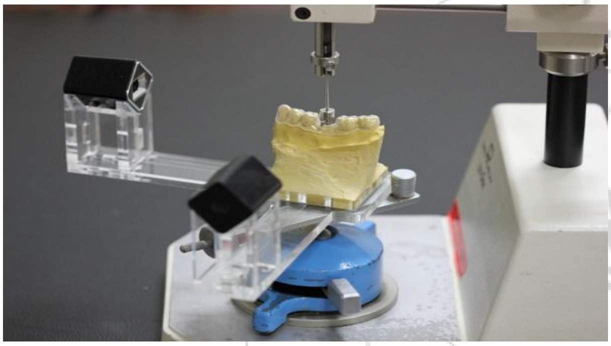

Figure 6: San device secured to the surveyor table.

San device were connected to the computer and the surveyor table was then shifted and rotated according to the verification sheet [13]. The corrected position was obtained when each trajectory superimposed the corresponding view from San device and the guiding cylinder was fixed by clear autopolymerizing acrylic resin [14]. The sleeve holder was removed after complete setting of the resin material, leaving the sleeve in position. The surgical guide was removed, finished and polished then delivered to the surgeon (Figure 7).

Figure 7: The CAD/MAM surgical guide.

The surgical procedure was performed according to the implant manufacturing instruction by the same clinician for all patients. The surgical guide was disinfected by submerging it in 70% ethanol for 15 minutes before insertion into the patient's mouth. It was tried in the mouth to check fitting and adequate interarch clearance for proper utilization. Local anesthesia was injected then mucoperiosteal flap was elevated and reflected by ligature suture, to the extent that it did not interfere with the seating of the surgical guide. The surgical guide was securely repositioned (Figure 8).

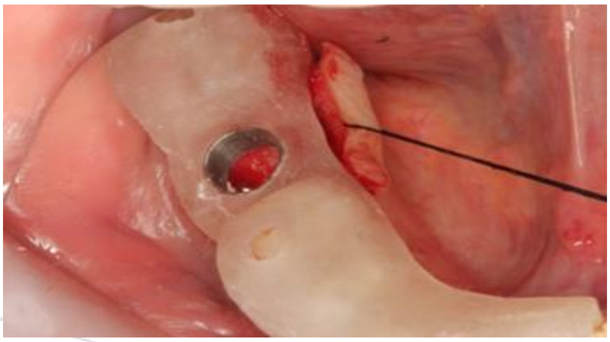

Figure 8: Reposition of surgical guide.

The Implantmed drilling unit (motor and handpiece) was used with a sufficient amount of Ringer's lactate solution as an irrigation coolant [15]. The titanium spoons and drills were used according to the user's guidelines. The UniGuide surgical kit allowed the controlled preparation of the implant bed through the surgical guide.
The drill was used in a straight up-and-down direction to facilitate irrigation and implant bed preparation until the bur stopped at the controlled depth. The recommended spoon and drill sequencing were utilized and the osteotomy was enlarged. The final bur used to finalize the implant bed preparation was selected from the surgical kit (Bicon) using the same implant diameter. This final bur was used without irrigation at a maximum of 50 RPM. The implant was seated, and then flap was sutured in position.

The post-operative CBCT was acquired with the same equipment and settings as the pre-operative CBCT by the same radiologists. The CBCT was taken after implant placement to verify the correct position relative to the adjacent teeth and vital structures. In addition it was used for evaluation of accuracy in this study. A postoperative CBCT was superimposed onto the virtual implant planning, using AccuGuide software in order to evaluate the deviations between the planned (virtual) and the placed (actual) implant [16], as shown in figure 8.

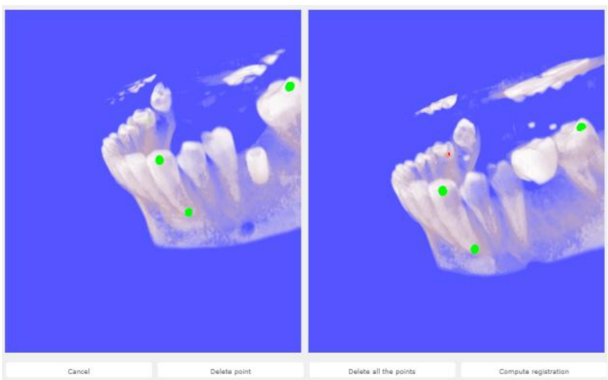

Figure 8: Superimposition of planned and placed implants.

To ensure a precise measurement of the deviations, the planned and placed implants from the AccuGuide software were stored as screenshots in the form of jpg files. Then imported into AutoCAD 2012 software, the deviations were measured after having determined the center points at the coronal and apical levels for both the virtual and actual implants (Figure 9).

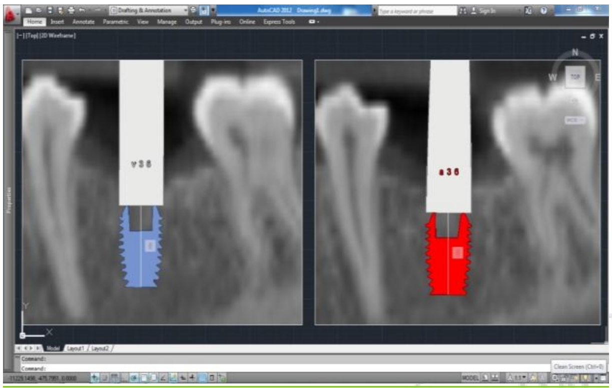

Figure 9: The planned and placed implants using AutoCAD 2012 software.

Statistical analysis was performed to evaluate all parameters differences between the virtually planned and actually placed implants. Descriptive statistics including the mean, median, standard deviation, minimum and maximum values were calculated. Shapiro-Wilk statistics were computed and revealed that the data distribution was normal. Accordingly, the one sample independent t-test was used to compare the group's mean to the thresholds of clinical acceptance of deviation between planned and placed implants. The conventional level of statistical significance (α=0.05) was applied. Analyses were conducted using SPSS v. 21.0.

3. Results

A total of 10 implants were successfully placed in 10 patients using CAD/MAM surgical guide. They were included 6 males and 4 females with a mean age of 31.7 years. They received 2 premolar and 8 molar implants, 8 in the mandibular arch and 2 in the maxillary arch.

Table 1: Descriptive statistics of the mesio-distal deviation parameters.

Variable	Mean	Median	SD	Min	Max
Coronal					
M-D CLD	0.20	0.18	0.14	0.05	0.5
M-D CDD	0.27	0.26	0.13	0.12	0.51
Apical					
M-D ALD	0.48	0.47	0.31	0.04	0.98
M-D ADD	0.29	0.28	0.18	0.11	0.64
M-D Angle	3.4	3.5	1.27	1	5

M-D CLD: Mesio-distal lateral deviation at the coronal level.
M-D CDD: Mesio-distal depth deviation at the coronal level.
M-D ALD: Mesio-distal lateral deviation at the apical level.
M-D ADD: Mesio-distal depth deviation at the apical level.

Table 2: Descriptive statistics of the bucco-lingual deviation parameters

Variable	Mean	Median	SD	Min	Max
Coronal					
B-L CLD	0.34	0.32	0.21	0.09	0.72
B-L CDD	0.30	0.25	0.15	0.14	0.62
Apical					
B-L ALD	0.53	0.42	0.34	0.12	1.03
B-L ADD	0.27	0.23	0.15	0.11	0.58
B-L Angle	3.5	4	1.78	1.78	6

B-L CLD: Bucco-lingual lateral deviation at the coronal level; B-L CDD: Bucco-lingual depth deviation at the coronal level; B-L ALD: Bucco-lingual lateral deviation at the apical level; B-L ADD: Bucco-lingual depth deviation at the apical level.

Table 3: Descriptive statistics of the global deviation parameters

Variable	Mean	Median	SD	Min	Max
Coronal					
GCD	0.52	0.49	0.19	0.3	0.9
Apical					
GAD	0.84	0.85	0.25	0.55	1.2
3D Angle	5.14	5.51	1.31	3	7.19

GCD: Global deviation at the coronal level.
GAD: Global deviation at the apical level.

4. Discussion

Prosthetic driven implant is a concept where the implant is placed in an optimal position for the prosthesis to function in a proper way. A precise placement of the implant is a prerequisite for this concept to be applied which is accomplished by surgical guides. They help the clinician to transfer the 3D implant position planned from the virtual 3D planning software to the patient's mouth [17].

Patients with a short posterior partially edentulous span were selected for this study. This helps in stabilization of radiographic template and the surgical guide onto the existing natural dentition to decrease the movement errors. Three windows on the occlusal surface of the surgical guide were prepared to be able to check its proper fitting [18].

The CBCT imaging system was selected, because of its isometric voxel size that is important for an accurate 3D model construction. In addition, its radiation dose is low [19].

The self-stopper, color-coded titanium drills of the Accuguide surgical kit, improved the precision of surgical guide, by reducing the lateral movement and stabilizing the guide through the drill key (spoon) handle [20].

The spoon (drill key) surgical guide was selected instead of standard guide (multiple guides, one for each drill size), for a better convenience [21]. The guide was placed only once and the spoons were easily used in sequence. In addition, a four millimeters height sleeve was used as it gives the same result of the sleeves that are 6 and 8 millimeters thick [22]. This reduction in height allowed more room for drill maneuvers,

and better accessibility and visibility during surgery.

The spoons were made of titanium, which reduces the friction between the drill and spoon, unlike the standard stainless steel spoons that produce more heat and may be abraded during function introducing metal chips inside osteotomy, which may lead to more complications [23]. The lateral arm of the spoon fits exactly in a buccal slot of the guiding sleeve in the surgical guide to secure it against movements [24].

The radiopaque composite resin (1mm diameter) was used into San reference plate to be accurately distinguished on the radiographic images. It eliminated errors that may result from scattering radiation or localizing the center of metal balls or rods used in conventional techniques [25]. The buccolingual distance between the radiographic markers did not interfere with the tongue nor with the cheek. In addition, the mesiodistal distance provided adequate landmarks.

The secured geometric transfer of the reference plate from the San mounting device to the San device enabled to view the reference points in perpendicular directions at the same height as the virtual planning. In this way the localization of the implant position was accurate in buccolingual, mesiodistal and coronoapical directions.

The calibrated transparent verification template used in this study, had no visual effect and was intimately adapted without any distortion on the monitor screen. Previous study used protractors to measure the angle manually, which lead to errors because of the distance between the protractor and the object [13].

The San device secured to surveyor model table, could be rotated freely, moved and secured in any position and angulation, due to the universal joint inside locking basket, which would enhance its precision. This is in contrast with other studies [9] that used teeth and serration in the joint, which resulted in limitation of movement and shift to the angle to the one side of tooth.

The San sleeve holder used to attach the guiding sleeve into the surgical guide without any drilling. This was accurate and simple. Many other researchers converted the radiographic template into surgical guide by drilling through the template, which resulted in vibration and movement of drilling axis leading to subsequent inaccuracy [26].

The results of this study showed that the discrepancy values obtained from the different parameters in CAD/MAM were acceptable, because of the patient's selection criteria, evaluation method and the software. This agrees with Behneke et al. (2012) who stated that, the discrepancy depends on the amount of remaining teeth and that the range of error in reduced residual dentition was 2-3 times as much as in a single tooth gap osteotomy [27].

Results of the present study were in agreement with the evidence of higher apical deviation values compared to the coronal value and also confirmed by Cassetta et al. [28]. Widmann et al. explained that it is essential to carefully distinguish between the accuracy achieved at the coronal level of the implant and the accuracy achieved at the apical level. Accuracy at the apical level is more important, as the apex is situated in the vicinity of vital anatomic structures. Naturally, the accuracy at the coronal level is always better because of the lack of angular deviation that is added by drilling further into the bone [16]. There was no statistical significant difference between the global apical deviation (GAD) of the planned and placed implants. Those results were in agreement with previous clinical studies [29], [30].

Regarding the 3D angle, a deviation of 5.14 degrees on average wasn't statistically significant. These results were in agreement with that reported by Schneider et al. (2014) who found a mean angular deviation of 5.73 degrees [30]. On the other hand, they were in disagreement with Tahmaseb et al. (2014) who recorded a maximum of 21.16 degrees [31] while in our study it was 7.1 degrees.

The global apical and global coronal deviations from this study were also comparable to those found in the study conducted by Cassetta in 2014 [32]. The results of this study supported the use of CAD/MAM, San technique as an acceptable transfer technique for fabrication of surgical guide. San device represented a handy, user-friendly and accurate tool to create manually fabricated surgical guides.

5. Conclusion

There are countless sources of error when applying guided surgery, some dependent on the operator, others not. Therefore, one needs to use ample precaution and continuous self-assessment during all steps of the planning, transfer and surgical procedure to avoid iatrogenic errors.

An individual surgical guide has proven to be useful, for the accurate placement of dental implant in the correct position.
Within the limitation of this study it could be concluded that, there was no statistically significant difference neither in global parameters measured at coronal and apical level nor at 3D angle of the planned and placed implants. The use of San technique appear to be an acceptable method, for manually fabricated surgical guide, based on virtual planning of dental implant.

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