Precision of the CAD/CAM Planmeca System Computer-Guided Surgery for the Placement of Dental Implants

by Dian Agustin Wahjuningrum

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Abstract

Dental implant systems using computer-aided surgical guide have advantages over the conventional procedures. A retrospective observational study was carried out to 56 dental implants placed according to surgical guide developed by CAD/CAM system. The guide included tooth-supported, and mucosa-supported surgical guide and implant placement in all areas of the jaws. The virtual planning was superimposed on a tomography to evaluate the precision parameters including platform distance, apex distance, angular deviation, and depth of implants.

Objectives to determine the accuracy of CAD/CAM system with a computer-aided surgery for dental implant placement based on the design and placement site.

Regarding the precision parameters, the platform distance was at 1.38 mm (± 0.66), the apex distance at 1.63 mm (± 0.97), the angular deviation at 3.97º (± 3. 34º) for, and the depth of implants at 1.11 mm (± 0.97). 0.72). The precision parameters had no significant difference on the implant placement in the jaws, but there was a significant difference on the platform distance (p = 0.0096) according to the guide. It has been found that the tooth-supported surgical guide had the best precision.

The precision of implant placement using computer-assisted surgical guides with the CAD/CAM system was maintained according to the antecedent precisión parameters. The guide design is a considerable factor for producing better precision as expected tooth-borne.

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Introduction

Background

Computer-aided surgery for dental implant placement is an approach that modifies the conventional protocols and becomes a new technology. Such a surgery method has been adapted to the needs of specialists to allow simplification and improvement in procedures; Thus, the approach encompasses a computer-aided design and manufacturing (CAD/CAM) system which includes virtual three-dimensional planning based on cone-beam computed tomography (CBCT) images, 3D printed virtual surgical guide and the surgical procedures using any implant systems with guided surgical kits.[1-6] The main advantages of this surgical method as indicated by Laleman, et al.[2]

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The success of the procedures lies in the precision of the computer-aided surgical method, which the final placement of implant in patients must coincide with virtual planned position[1-21]. Since the introduction of the method, various investigations have been carried out by Pettersson, et al.[3] Cristache, et al.[4], Beretta, et al.[9], and Geng, et al.[8] to determine the precisión and obtain sufficient security and confidence in the use of that guided surgery. The precision parameters evaluated were three-dimensional discrepancies between the platform, apex, and angulation of the realized implant position with the planned ones.

Another parameter to consider is the design of the surgical guide. Lee et al.[6] add another precision parameter, which is the depth of implants. Likewise, they have reported that there was statistically significant difference in the precisión of guide designs, in which tooth-borne surgical guide was the most accurate. The precision by the implant placement is also studied by Cristache et al.[4] They have found that there was greater precision of the implant placement in the mandible, especially the maxilla.

Another precision parameter to consider is the experience of the operator as demonstrated by Rungcharassaeng et al.[6] or Gillot et al.[9] They have found that there was statistically significant difference in the depths of implant placement observed from experience of the operator. It concludes that experience plays an important role in obtaining greater precision. Finally, some studies have been developed to evaluate precisión. Bover Ramos et al.[5] conclude that it is necessary to carry out clinical studies on in vitro or cadaveric patients due to the greater complexity demanded.

Objectives to determine the precision of implant placement which uses the Planmeca CAD/CAM system with computer-aided surgical method according to the guide design and dental implant placement site.

Materials and methods

	Total	Number of guides	Number of implants
Number of patients	12		
Number of guides	fifteen		
Number of implants	56		
Guide layout			
Toothless (DS)		5	25
Dentomucosoportadas (DMS)		5	17
Mucosa-supported (MS)		2	14
Place of implantation			
Maxilla anterior area		6	eleven
Maxilla posterior area		8	24
Anterior jaw area		one	2
Jaw posterior area		6	19

Table 1. Descriptive characteristics of computer-guided implant surgery treatments.

Research Samples

A retrospective observational study was carried out after a pilot study that involved 10 cases obtained a precision value at the implant apex of 1.57 ± 0.60 and considered the previous precisión value of 1.17 ± 0.63 for the same parameter in the research of Cristache C et al. (2017). Using the 95% confidence level, this study obtained the statistical power of 90%. Finally, there were 56 virtual implants placed in 12 patients to be observed, which included the sample from the pilot study (See Table 1). This study has obtained an ethical approval from the ethics committee of the Universidad Científica del Sur, Lima, Perú.

Research procedures

Data search was done on some databases of the Instituto de Diagnóstico Maxilofacial (IDM), Lima, Perú, where tomographic images were collected from patients who underwent multiple dental implant placement protocols using the Planmeca® CAD/CAM system in a guided surgery (Helsinki, Finland).

Preoperative CT scans were acquired by the Promax 3D Mid tomograph (Planmeca®) and had a field size of 10x10cm and voxel size of 200 microns. The scans of the physical models with and without diagnostic wax-up were obtained using the PlanScan® Lab (Planmeca®) structured light (LE) tabletop scanner with precision of 5 microns. The virtual planning was carried out with the Romexis 5.3 implant module (Planmeca®) in which implants from various commercial houses were included (Conexão®, Brazil; Dentium®, Korea; Sweden & Martina®, Italy, Neodent®, Switzerland and GMI®, Spain), all the selected guides were developed to use full guided implant placement surgical kid and following the indications of each commercial brand. The virtual planning of the implants was carried out by a maxillofacial radiologist operator, with experience in the CAD / CAM flow of the Planmeca system and in conjunction with 5 implantologist operators with experience in guided surgery; Each of them were in charge of a respective trademark and were the ones who made the selection of the diameter, length, position of the implant in the tomography and the implant placement surgery. The guides were materialized using the Creo 3D printer (Planmeca®) with a digital light processing technology (DLP) of 2mm thickness based on light-cured resin.

Post-operative CT scans were obtained for various indications, nine scans were obtained for the realization of a new planning and preparation of a surgical guide for the placement of new implants in the jaw not operated; Three scans were performed to rule out complications of probable bucco-sinus communication, due to the very narrow position of the implants with the maxillary sinus, in all scans the ULD technology (Planmeca® Ultra-Low DoseTM) of low radiation dose was used.

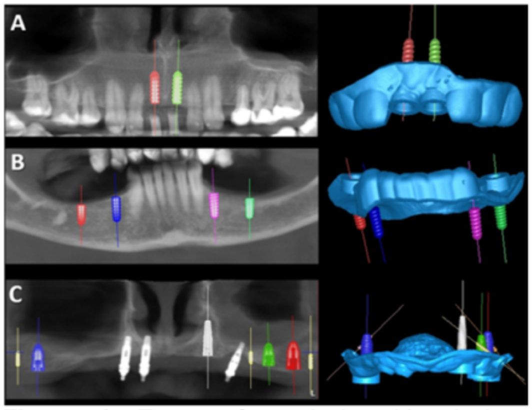

Figure 1. Types of surgical guide designs developed by the guided surgery module of the Romexis 5.3 software (Planmeca®, Finland). A: Tooth-supported; B: Dentomucosupported and C: Mucosupported.

Research accuracy assessment

Figure 1 shows the three-dimensional position of the inserted implant compared to the planned position was assessed using the "Embedded from 3d models" tool of the Romexis 5.3 software.

The virtual planning and the preoperative tomography were converted to STL format using "3D growth" tool in bone tissue option and then merged to the control tomographic volumes, the pairing was performed by matching 3 reference points at bone and dental level (two posterior and one anterior) in each volume and by means of an automatic adjustment performed by the software (as shown by figure 2).

In the fused volumes, transaxial cuts were made at the level of the jaws in which the following precision measurements were carried out: 1) Distance from the implant site, length in millimeters (mm); 2) Apex distance, length in millimeters (mm); 3) Implant angulation, in degrees (°) and 4) Depth of the implants concerning the major axis of the virtual implants, in millimeters (mm) (as shown by figure 3).

Statistical analysis

Descriptive statistics were performed to show the precision values. The Anova statistical tests was performed for more than two independent simples, and the Kruskal-Wallis test was used to analyze non-parametric data. These statistical tests could compare precision values according to the guide designs or implant site.

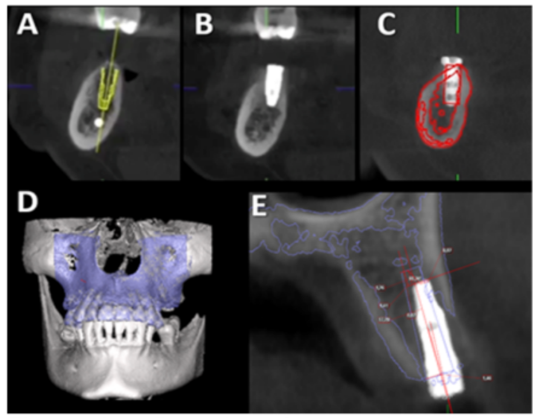

Figure 2. Procedure for superimposing the virtual planning with the control tomography. A: Virtual planning of a dental implant in the posterior area of the jaw; B: Control tomography with the implant in the real position; C and D: Superposition of the STL of the virtual planning and the presurgical tomography with the control tomography; E: Measurement of precision parameters.

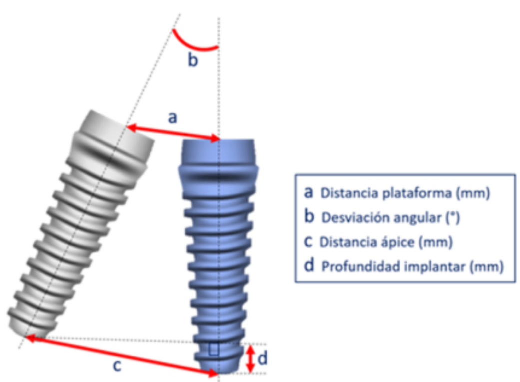

Figure 3. Parameters for evaluating implant precision. Virtually planned implant (blue) vs implant placed in real position (Grey)

Results

A total of 56 implants were evaluated. The results show a precisión value of platform distance at1.38 mm (± 0.66; 0-3.1), the apex distance at 1.63 mm (± 0.97), the angular deviation at 3.97° (± 3 34°), and the Depth of implants at 1.11 mm (± 0.72).

Precision	DS	DMS	MS	Total			P value *
	Mean (DS)	Mean (DS)	Mean (DS)	Mean (DS)	Min	Max	
Platform distance (mm)	1.10 (0.41)[a]	1.72 (0.55)[b]	1.48 (0.92)[c]	1.38 (0.66)	0	3.1	0.0096[d]
Distance apex (mm)	1.38 (0.60)	2.03 (1.07)	1.60 (1.02)	1.63 (0.97)	0.2	4.64	0.13
Implant angulation (°)	3.55 (3.32)	4.61 (3.72)	3.95 (2.99)	3.97 (3.34)	0.2	14.31	0.47
Implant depth (mm)	0.87 (0.40)	1.22 (0.82)	1.39 (0.94)	1.11 (0.72)	0.1	3.21	0.24

Table 2. Precision of the computer-guided surgery method for dental implant placement according to the surgical guide design. The different superscript letter are statistically different (Kruskall-Wallis, P<0.05)
DS: Tooth-supported, DMS: Tooth-supported, MS: Muco-supported

According to the guide design, the tooth-borne surgical guide had better values in all precision parameters. The difference in precisión parameters was only statistically significant (p= 0.0009) shown by table 2 when the tooth-supported surgical guide was compared with the tooth-supported surgical guide in terms of platform distance (1.10 + -0.41 vs 1.72 + -0.55). The precision parameters had not significant difference if seen from the implant placement in the jaws.

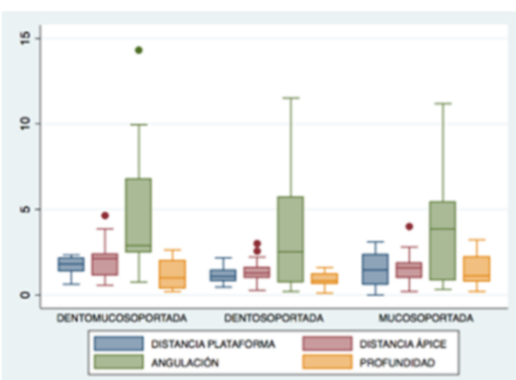

Figure 4. Precision parameters according to the design of the surgical guide.

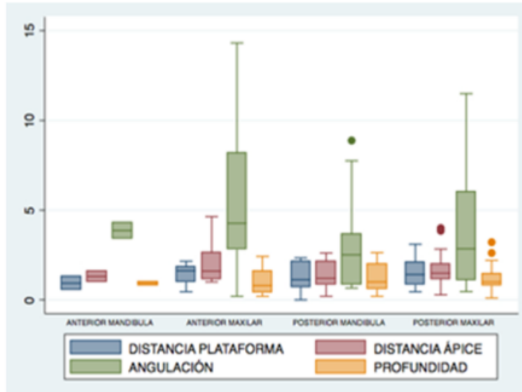

Figure 5. Precision parameters according to the place of dental implant placement.

Precision	Anterior maxilla	Posterior maxilla	Anterior jaw	Posterior jaw	P value *
	Mean (DS)	Mean (DS)	Mean (DS)	Mean (DS)	
Platform distance (mm)	1.43 (0.53)	1.50 (0.69)	0.92 (0.50)	1.27 (0.69)	0.51 *
Distance apex (mm)	1.97 (1.10)	1.70 (0.92)	1.30 (0.43)	1.39 (076)	0.50 **
Implant angulation (°)	5.49 (4.18)	4.23 (3.55)	3.86 (0.61)	2.78 (2.30)	0.34 **
Implant depth (mm)	0.99 (0.70)	1.12 (0.74)	0.92 (0.14)	1.12 (0.77)	0.91 **

Table 3. Comparison of the precision of the computer-guided surgery method according to the implant placement site.
* ANOVA
** Kruskall-Wallis

According to the guide design and implant site shown in the graphs of the box plots (as shown by figures 4, 5, and table 3), the implant angulation was the only one that presented a greater precision deviation. It considers an A value close to 0 which had the highest precision.

Discussion

The implant placement using computer-aided surgical guide had high precisionbut many factors would determine the greatest possible success and the use of the CAD / CAM in the procedures. In the present study, the precision of implant placement was evaluated using the Planmeca® CAD / CAM system with computer-aided surgical guide. The precision values of this system ranged from 1.11mm (depth of implant) to 1.63mm (apex distance). Values close to 0 refer to high precision of the system. Some variables could influence, for example the different implant systems used for a guided surgery.

Regarding the effect of precision on the implant site in the maxilla, Cristache et al.[4] have obtained precision values of 0.798mm (DS: 0.52) for the distance of the platform, 1.17 mm (DS: 0.63) for the distance of the implant apex and 2.34 (DS (0.85) for an average angular deviation. Also, they have found statistically significant difference according to the implant placement, obtaining greater precision between the implant placement in the mandible and in the maxilla. Gillot et al.[10] have also found differences in precision in terms of the implant site, but greater precisión was highlighted in the maxilla than in the mandible. In contrast to both previous studies, this present study shows no statistical difference in precisión not only according to the arch but also the area of the dental groups (anterior and posterior) that could affect the final precision values.

Regarding the precision values according to the guide, Lee et al.[6] have determined that systems with metal attachments were adaptable to the guide which produced fewer angular deviations. Geng et al.[8] mention the depth of implants was measured between the virtual implant apex and the real implant apex following the axis of the virtual implant. They have found that tooth-borne surgical guide can be more precise than tooth-supported surgical guides; This present study points out the lower deviations of the precision parameters were at 1.10mm (0.41) for the platform, 1.38mm (0.6) for the apex, 3.55 ° (3.32) for the angulation and 0.87mm (0.40) for the depth of implants placement when using tooth-supported surgical guide in front of the two other evaluated designs. The classification of the designs is conformed according to the support of the guide and the edentulism of dental patients.

To evaluate the precision parameters of guided surgery, Bover Ramos et al.[6] conduct a systematic review and meta-analysis review that cadaveric, in vitro, and clinical studies should be performed clinically to obtain more accurate results as the precisión value of dental implant placement was lower in clinical and cadaveric studies than in vitro studies due to different clinical management.

The precision and advantage of computer-aided surgery for dental implants have a direct effect on the patient well-being. This idea is demonstrated by Youk, et al.[22] by saying that patients undergoing this treatment had greater satisfaction compared to those under a conventional surgery. Demonstrating the precision has been quite tedious since it needs the support of other non-dental software to obtain high precisión. However, this present investigation shows the tools of the different tomographic software such as Romexis 5.3 are being developed and allow the same clinical evaluation on the placement of dental implants. Above all, the main limitation of the technology lies on the high cost of the procedures.

Evaluating the precision using CBCT is not ideal as it leads to a post-operative scan of the dental patients and the radiation dose that it implies. Other technologies such as dynamic navigation allow to overcome this obstacle but are rarely used. The present technology can obtain tomographic equipment with low radiation dose as described by Yeung, et al.[23]. They assert this technology can have less radiation dose by reducing the exposure factor such as milliamperage (ma) and kilovoltage (Kv); however, image quality is sacrificed as the voxel size greatly increases. The difficulty in post-operative evaluations does not represent the major limitations since it seeks to evaluate complications due to the implant site or plans in the future.

Conclusions

The precision of implant placement using computer-assisted surgical guides with the CAD/CAM system was maintained according to the antecedent precisión parameters. The guide design is a considerable factor for producing better precision as expected tooth-borne.

Acknowledgements

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Declaration of Interest

The atuhors declare that there are no conflicts of interest.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6