Accuracy of Positioning of Implants Inserted Using a Mucosa-Supported Stereolithographic Surgical Guide in the Edentulous Maxilla and Mandible

Michele Cassetta, DDS, PhD[1]/Matteo Giansanti, DDS[2]/
Alfonso Di Mambro, DDS[2]/Luigi Vito Stefanelli, DDS, DEng[2]

Purpose: *The aim of this study was to evaluate the accuracy of implants inserted using a mucosa-supported stereolithographic surgical guide and to determine the influence of surgical management of the guide (fixed or unfixed), arch (maxilla or mandible), and smoking habit (normal or hyperplastic mucosa) on accuracy.* ***Materials and Methods:*** *In completely edentulous subjects, preoperative computed tomography (CT) was performed, and the images were used to plan implant positions. After the implants were placed, CT was performed again, and the presurgical and postoperative images were compared. With computer software, the jaw contours from the two CT scans were matched and the deviations between the planned and actual implant positions were evaluated. Surgical technique, arch, and smoking habit were examined as independent variables, and their influence on accuracy was evaluated with a t test.* ***Results:*** *Twenty-eight surgical guides (225 implants) were included in this study. Deviations between planned and actual positions were seen in the global coronal (mean ± SD: 1.68 ± 0.6 mm), global apical (2.19 ± 0.83 mm), and angular (4.67 ± 2.68 degrees) dimensions. Fixation of surgical guides (fixed: 4.09 degrees; not fixed: 5.62 degrees) and use of the guide in the maxilla (4.36 degrees; mandible: 5.46 degrees) resulted in statistically significantly less angular deviation (ie, better accuracy). Nonsmoking patients showed statistically significantly better accuracy in global coronal (nonsmokers: 1.54 mm; smokers: 1.83 mm) and global apical (nonsmokers: 2.08 mm; smokers: 2.27 mm) deviations.* ***Conclusion:*** *The greater supporting surface of the maxilla and fixation of the surgical guide improved the accuracy of the guides. The reduced mucosa thickness in nonsmokers decreased global coronal and global apical deviation.* Int J Oral Maxillofac Implants 2014;29:1071–1078. doi: 10.11607/jomi.3329

Key words: *accuracy, guide, computer-assisted image processing, dental implants, edentulous, stereolithography, surgical guide, three-dimensional imaging*

A single stereolithographic surgical guide for both osteotomy site preparation and implant delivery is currently used[1–8] for guided surgery. This fully guided surgical approach is advocated to minimize the deviations that occur when implants are placed freehand,[4] but few clinical studies have evaluated the accuracy of the guided method.[5–11] However, it is essential for the clinician to be aware of the degree of accuracy of the chosen surgical method, as well as the conditions that may influence the degree of accuracy.[12] In this paper, accuracy is defined as the measurement of the degree of three-dimensional (3D) deviation of the placed implant from the virtually planned implant position.

The purpose of this study was to address the question: In edentulous patients, what is the deviation between planned and actual implant positions when a mucosa-supported surgical guide (External Hex Safe, Materialise Dental) is used? The investigators hypothesized that there would be differences between the virtual planned and the actual positions of the implants inserted using computer-aided implant dentistry and that the factors of surgical technique (ie, the use of a fixed or unfixed guide), arch type (maxillary or mandibular), and smoking habit may also affect the accuracy of implant insertion when this type of surgical guide was used. The specific aims of this study were to estimate the deviation between the planned and actual implant

[1]Assistant Professor, Department of Oral and Maxillofacial Sciences, "Sapienza" University of Rome, Italy, School of Dentistry.
[2]Research Assistant, Department of Oral and Maxillofacial Sciences, "Sapienza" University of Rome, Italy, School of Dentistry.

Correspondence to: Michele Cassetta, Department of Oral and Maxillofacial Sciences, "Sapienza" University of Rome, School of Dentistry, Via Caserta 6, 00161 Rome, Italy. Fax: +39-06-5016612. Email: michele.cassetta@uniroma1.it

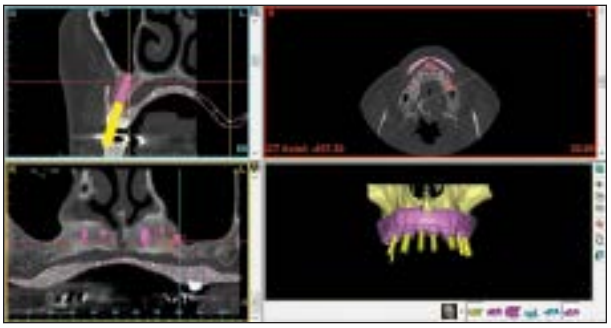

Fig 1 The four interactive windows of the implant planning software.

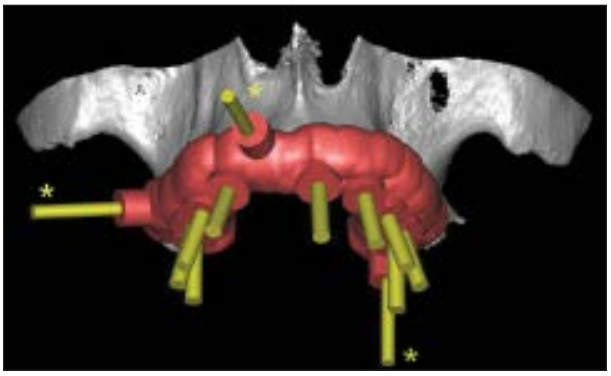

Fig 2 The design in the CAD environment of a maxillary mucosa-supported surgical template to guide the insertion of eight implants. Three osteosynthesis screws (*asterisks*) were virtually placed to fix the surgical guide in the bone.

positions and to identify factors associated with deviations between planned and actual implant positions.

MATERIALS AND METHODS

Study Sample

An observational retrospective study was performed in a population of patients treated at the Department of Oral and Maxillofacial Sciences, "Sapienza" University of Rome, with an implant prosthetic rehabilitation between February 2007 and January 2013.

Only patients with a completely edentulous arch (maxilla or mandible; any remaining dental elements had been extracted at least 3 months prior to the implant-prosthetic rehabilitation) were included in the study sample. Regular smokers (defined as more than 10 cigarettes a day) were not excluded; this allowed the division of the study population into smoking and nonsmoking subgroups. However, patients with systemic health problems, parafunctional habits, poor oral hygiene, severe alveolar bone deficiencies (absence of sufficient alveolar bone to support at least six implants at least 3.75 mm in diameter and 11.5 mm in length), uncontrolled diabetes, current irradiation to the head or neck, psychologic disorders, and/or alcohol or drug addiction were excluded. This study followed the Declaration of Helsinki on medical protocol and ethics.

Techniques

The surgical technique (fixed or unfixed), arch (maxilla or mandible), and smoking habit were taken as independent variables, and their influence on accuracy was evaluated. The first phase of treatment involved the creation of a radiopaque diagnostic template (Scanno-Guide), which is an exact replica of a relined removable prosthesis that had been accepted by the patient and met his or her identified esthetic and functional requirements. Computed tomographic (CT) scans of the patient's arch were performed with a spiral CT device (Asteion Multi, Toshiba Medical Systems). The preoperative and postoperative CT parameters used were: 0 degrees of gantry tilt, nominal slice widths of 0.5 mm for axial scans.

The scans, which included the Scanno-Guide to integrate the anatomical data with the functional and esthetic requirements, were taken without interarch contact. An occlusal index was used to prevent overlapping between the images of the opposite arch and the radiopaque diagnostic template. The major potential source of bias of the study (systematic methodologic error) was reduced by verifying the absence of air pockets between the radiologic template and the alveolar mucosa during CT scans. The absence of air pockets between the radiographic template and the mucosal tissue indicated perfect fit of the Scanno-Guide.

The potential locations for implant placement and the corresponding implant length and width were planned using SimPlant (Materialise Dental). This computer program uses the original CT data, in digital format, to produce axial, 3D, panoramic, and cross-sectional images and makes all of them visible in four interactive windows on a computer monitor (Fig 1). With this software, the implants were virtually placed according to bone anatomy and prosthetic designs, and a computer-aided design of the surgical guide was developed (Fig 2). The surgical guide (Safe, Materialise Dental), which would be used to transfer the digital planning to the surgical environment, was created using stereolithography. The surgical guides were employed in each subject to accommodate two specific drills of increasing diameters during osteotomy preparation and did not require flap reflection. The punching of the gingival tissues was performed before preparation of the alveolar implant sites.

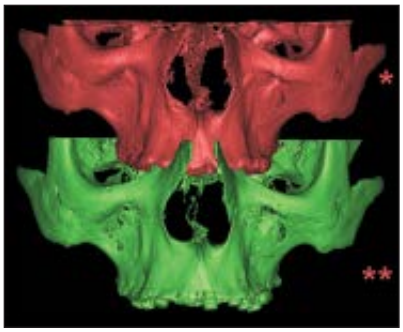

Fig 3 The overlapping of (*red*) preoperative 3D representations of maxillary CT images and (*green*) postoperative imaging using Mimics software.

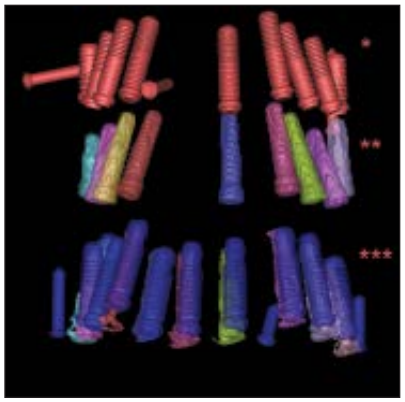

Fig 4 Three-dimensional representations of (*top row*) planned and (*middle row*) inserted implants at the time of coordinate transformation operations. *Bottom row*: Matching of positions using Mimics software.

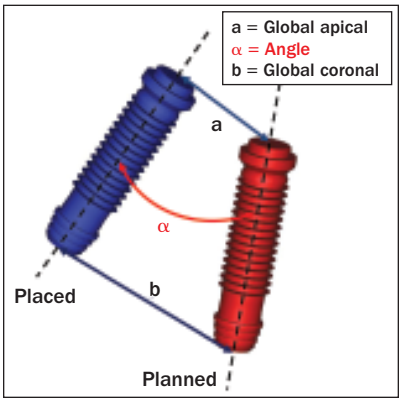

Fig 5 Three-dimensional evaluation of planned (*red*) and placed (*blue*) implant positions. α = angular deviation (in degrees) between planned and placed implant axes; a = global coronal deviation, ie, the linear distance (in millimeters) between planned and placed implants at the neck; b = global apical deviation, ie, the linear distance (in millimeters) between planned and placed implant at the apex.

Cylindric implants (PRIME, Impladent) with an external hexagon (diameter 3.75 mm and lengths ranging from 10 to 15 mm) were inserted in the edentulous maxillae and mandibles.

The surgical guide allowed control of implant site preparation and implant insertion, together with osteotomy site-specific drills with vertical stops that controlled the depth of implant site preparation and specific delivery mounts (implant holder: diameter 4.00 mm, length 4 to 15 mm). In some cases, after the surgeon verified precise seating of the guide and checked the occlusal relationships with the opposing dentition or the antagonist prosthesis using the same occlusal index used during the CT scans, the surgical guide was fixed to bone with at least three osteosynthesis screws (mean diameter of 2 mm and mean length of 12 mm) placed in a tripod formation and horizontally and vertically oriented (Fig 2).

All patients underwent postoperative CT scanning, and the preoperative and postoperative images were superimposed and compared.

To calculate the deviations between the planned (virtual) and the placed (actual) implants, object registration was performed to align the preoperative 3D representations of the arches with their counterparts in the postoperative images. An iterative closest point algorithm (the software runs until it finds the best overlap between the images of preoperative and postoperative arches) was used to match the arches (Fig 3).

The established coordinate transformation operations were therefore applied to the 3D representations of the planned and placed implants to allow for relative comparisons between the preoperative and the postoperative implant positions (Mimics, Materialise) (Fig 4). Three deviation parameters (ie, global coronal, global apical, and angular) were defined and calculated between the planned and the placed implants using the coordinates of their respective apical and coronal points (Fig 5). Global deviation was defined as the 3D distance between the coronal (or apical) center of the corresponding planned and placed implants. Angular deviation was calculated as the 3D angle between the longitudinal axes of the planned and placed implants.[8] Overlap of the arches and the measurements were performed automatically by the Mimics software. Mimics runs until it finds the exact overlap between the images of the preoperative and postoperative arches and does not require any intervention by the examiner, thus excluding any possible human measurement error.

To determine the possible influence of a smoking habit on accuracy with regard to mucosal thickness, additional measurements of mucosal thickness were made with the SimPlant software (Materialise Dental). The reference points for this measurement were defined for each arch. The reference points in the maxilla were located in the first molar, first premolar, and canine regions bilaterally as well as the right lateral incisor region (Fig 6). In the mandible, the reference points in the radiographic template were in the same seven areas (Fig 7). A line parallel to the long axis of the tooth was traced from the base of the template to the center of the alveolar ridge to measure mucosal thickness (Figs 6 and 7).

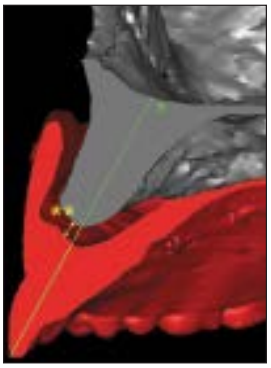

Fig 6 Evaluation of mucosal thickness in the maxillary right lateral incisor region. The green line is parallel to the long axis of the tooth. The mucosal thickness (*yellow line*) was defined as the distance between the surface of the alveolar crest and the base of the scanning template.

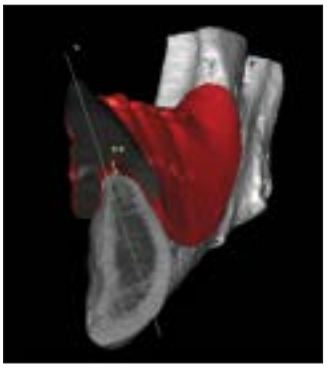

Fig 7 Evaluation of mucosal thickness in the mandibular right canine region. The green line is parallel to the long axis of the tooth. The mucosal thickness (*yellow line*) was defined as the distance between the surface of the alveolar crest and the base of the scanning template.

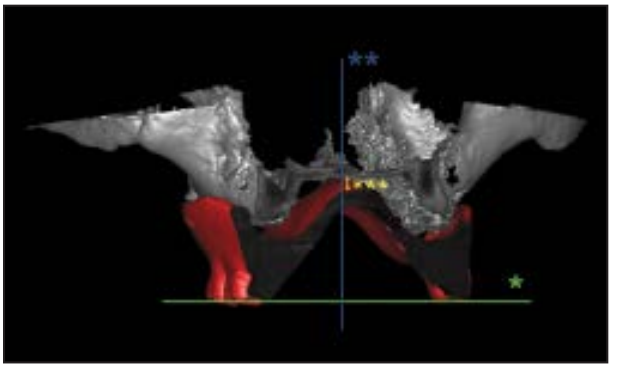

Fig 8 Evaluation of midpalatal suture mucosal thickness at the first molar level. *Green line* = between right and left first molar/second premolar contact points. *Blue line* = perpendicular to the first line. The yellow line indicates the distance between the midpalatal suture of the hard palate and the base of the scanning template.

Table 1 Subjects and Treatment Characteristics

Characteristic	No. (%)
Total no. of guides	28
Sex	
Male	22 (78.6)
Female	6 (21.4)
Arch	
Maxilla	18 (64.3)
Mandible	10 (35.7)
Guide type	
Fixed	18 (64.3)
Not fixed	10 (35.7)
Smoking habit	
Smokers	14 (50)
Nonsmokers	14 (50)
Mean age (y)	58

To record the mucosal thickness at the midpalatal suture level, a line was drawn from the contact point between the right second premolar and the right first molar to the contact point between the left second premolar and the left first molar. A second line, perpendicular to the first one and passing through the midpalatal suture, was then drawn, and the distance between the base of the scanning template and the midpalatal suture was measured (Fig 8). Likewise, a measurement was made with the same method based on a line passing through the contact point between the right canine and the right first premolar to the contact point between the left canine and the left first premolar.

Statistical Analysis

Quantitative data were described using mean values (means of absolute values) and standard deviations (SDs). The statistical analysis was conducted on the level of the surgical guide.

The deviation data were also described by dividing the sample into the following groups: fixed guide vs unfixed guide, maxilla vs mandible, and smoker vs nonsmoker. The *t* test was used to determine the influence of surgical technique (with/without stabilization screws), arch (maxilla/mandible), and smoking habits (smokers/nonsmokers) on accuracy. Significance was set to $P \leq .05$. The *t* test was also used to determine whether there was a statistically significant difference in the mucosal thickness of smokers and that of nonsmokers. Significance was set to $P \leq .05$. The data were analyzed using SPSS for Windows software (Statistical Package for Social Science, IBM Corporation).

RESULTS

Twenty-eight surgical guides were used (20 patients; 8 subjects were treated in both arches), and a total of 225 implants were planned and inserted. Twenty-seven surgical guides were used to insert eight implants per arch, and one guide was used to insert nine implants.

There were no reports of anesthesia, paresthesia, abnormal hemorrhages, sinus pathologies, or complications related to the anatomy or to inaccurate placement of the implants.

Table 2 Global Coronal, Global Apical, and Angular Deviation Values

Type of deviation	Mean	SD
Coronal deviation (mm)	1.68	0.6
Angular deviation (deg)	4.67	2.68
Apical deviation (mm)	2.19	0.83

Table 3 Deviations (Means ± SDs) of Planned and Placed Implants, Divided on the Basis of Surgical Technique, Arch, and Smoking Habit

Factor	Apical deviation (mm)	Coronal deviation (mm)	Angular deviation (deg)
Surgical technique			
Fixed	2.09 ± 0.75	1.66 ± 0.58	4.09 ± 2.40
Unfixed	2.26 ± 0.89	1.68 ± 0.60	5.62 ± 2.80
Arch			
Maxilla	2.12 ± 0.78	1.68 ± 0.51	4.36 ± 2.90
Mandible	2.25 ± 0.88	1.64 ± 0.71	5.46 ± 2.03
Smoking habit			
Smokers	2.27 ± 0.83	1.83 ± 0.58	4.50 ± 2.87
Nonsmokers	2.08 ± 0.80	1.54 ± 0.56	4.92 ± 2.52

Table 4 Statistical Analysis of the Influence of Template Fixation, Arch, and Smoking Habit on Deviation

Factor	*P* value	Difference between means	Standard error
Fixed vs unfixed guide			
Coronal deviation (mm)	.777	–0.02329	0.08202
Angular deviation (deg)	.000**	–1.53425	0.35022
Apical deviation (mm)	.183	–0.15079	0.11283
Maxilla vs mandible			
Coronal deviation (mm)	.766	0.02527	0.08469
Angular deviation (deg)	.001**	–1.22216	0.36786
Apical deviation (mm)	.193	–0.15212	0.11653
Smokers vs nonsmokers			
Coronal deviation (mm)	.000**	0.32356	0.07742
Angular deviation (deg)	.334	–0.34560	0.35694
Apical deviation (mm)	.022**	0.25351	0.10972

**Statistically significant (*t* test; $P \leq .05$).

Table 5 Analysis of the Difference in Mucosal Thickness Between Smokers and Nonsmokers

	Mean mucosa thickness (mm)	Difference between means	*P* value	Standard error
Smokers	4.0903	1.10227	.000**	.16458
Nonsmokers	2.9880			

**Statistically significant (*t* test; $P \leq .05$).

Subjects and treatment characteristics are summarized in Table 1. The global coronal (mean: 1.68 mm), global apical (mean: 2.19 mm), and angular (mean: 4.67 degrees) deviations were determined via the image registration technique and are reported in Table 2.

When the influence of surgical technique was considered, the implants inserted using a fixed guide showed mean global coronal deviation of 1.66 mm, mean global apical deviation of 2.09 mm, and mean angular deviation of 4.09 degrees. When the implants were inserted using an unfixed surgical guide, mean global coronal deviation of 1.68 mm, mean global apical deviation of 2.26 mm, and mean angular deviation of 5.62 degrees were recorded (Table 3). The implants inserted in the maxilla (mean global coronal deviation: 1.68 mm; mean global apical deviation: 2.12 mm; mean angular deviation: 4.36 degrees) showed a different accuracy compared to the implants inserted in the mandible (mean global coronal deviation: 1.64 mm; mean global apical deviation: 2.25 mm; mean angular deviation: 5.46 degrees) (Table 3). With respect to smoking habit, the implants inserted in nonsmokers showed mean global coronal deviation of 1.54 mm, mean global apical deviation of 2.08 mm, and mean angular deviation of 4.92 degrees; in smokers, the deviation values were 1.83 mm for mean global coronal deviation, 2.27 mm for mean global apical deviation, and 4.50 degrees for mean angular deviation (Table 3).

Analysis of the results with the *t* test showed that surgical technique and arch both exerted a significant effect on the accuracy of angular deviation (Table 4). Paired comparisons demonstrated that the use of screws to fix the guide resulted in better accuracy in comparison to unfixed surgical guides. Implants placed with a fixed guide showed statistically significantly less angular deviation ($P = .000$) (Table 4). Regarding the influence of the arch (maxilla or mandible) on accuracy, the *t* test showed statistically significantly less angular deviation ($P = .001$) when a stereolithographic surgical guide was used in the maxilla (Table 4). A statistically significant difference was found between smokers and nonsmokers when comparing global coronal ($P = .000$) and global apical ($P = .022$) implant deviations; otherwise, no significant differences were found in angular deviations of these two groups (Table 4). The mean values of mucosal thickness in smokers and nonsmokers were 4.09 mm and 2.98 mm, respectively; analysis with the *t* test showed a statistically significant difference in mucosa thickness between smokers and nonsmokers ($P = .000$) (Table 5).

DISCUSSION

The purpose of the present study was to evaluate the accuracy of implant placement using a mucosa-supported stereolithographic surgical guide and to evaluate the influence of three variables—surgical technique, arch, and smoking habit—on the accuracy of implant insertion. The results of this study confirmed the hypothesis that surgical technique affected accuracy, as the fixed surgical guides provided a higher level of accuracy; the authors suggest that this is a result of the reduced possibility of displacement of the guide. Similarly, the arch affected accuracy, perhaps because the reduced area of support in the mandible may allow a greater possibility of guide displacement. Finally, the hypothesis that smoking habit affected accuracy was also supported, and the authors postulate that the greater average thickness of smokers' mucosa resulted in this poorer accuracy. A possible explanation for this is the increased distance between the bottom of the tube of the surgical guide and the entry point (ie, the point of entry of the surgical bur at the alveolar ridge).

Comparison of the results of this study to other studies published on this topic is hindered by the many different methods, both analog and digital, devised by various authors to measure deviations. In particular, few clinical studies have used digital conversion software exclusively to match preoperative planning with postoperative images. Arisan et al[13] reported accuracy data comparable to that of the present study. These authors found, in the case of mucosa-supported guides (11 mucosa-supported guides firmly fixed by osteosynthesis screws), a mean angular deviation of 2.9 degrees (range, 0.8 to 3.5 degrees; SD, 0.39 degrees), a mean global coronal deviation of 0.7 mm (range, 0.2 to 0.83 mm; SD 0.13 mm), and a mean global apical deviation of 0.76 mm (range, 0.4 to 0.99 mm; SD 0.15 mm). According to these authors,[13] the smaller deviations were a result of less guide movement in completely edentulous patients. The use of specific osteotomy drills through a single guide and the integration of a depth-control mechanism were recommended by the same authors to reduce deviations and to ensure safe osteotomies and accurate positioning of the implants.[13]

D'Haese et al,[14] in a prospective clinical study of the accuracy of a mucosa-supported stereolithographic surgical guide used in edentulous maxillae, described the deviations measured between 77 planned and placed implants. As in the current study, the authors[14] used software (Mimics, Materialise) to fuse the images of the virtual and actual implants. The global coronal deviation ranged between 0.29 and 2.45 mm (SD, 0.44 mm), with a mean of 0.91 mm; the mean angular deviation was 2.60 degrees (range, 0.16 to 8.86 degrees; SD, 1.61); and the mean apical deviation was 1.13 mm (range, 0.32 to 3.01 mm; SD, 0.52 mm). The authors[14] asserted that the deviation values of the study were somewhat lower than those previously published, as only entirely mucosa-supported guides were used. These guides, which cover a maximum of soft tissues to improve stability, were also correctly fixed to the supporting soft tissues with a sufficient number of fixation screws.

In a recent study of the accuracy of the template-guided implantation system NobelGuide (Nobel Biocare) conducted by Vasak et al,[11] a newly developed fusion method was used to superimpose postoperative CT data on preoperative CT data. Although the method used by these authors[11] for the overlapping of preoperative and postoperative images is different from the method used in the current study, the accuracy is comparable (maximum linear deviation: 2.02 mm; maximum angular deviation: 8.1 degrees) to that seen in the present study. The same authors[11] also highlighted significantly smaller deviations for implants inserted in anterior arches than for those inserted in posterior regions and significantly smaller deviations for implants inserted in the mandible than in the maxilla, but only in the mesiodistal direction. As stated by Widmann and Bale,[6] it is essential to distinguish between the accuracy achieved at the base of the implant and the accuracy achieved at its tip. According to these authors, accuracy at the tip is considered more important, as the tip is situated in the vicinity of vital anatomical structures,[6] whereas accuracy at the base is desirable as it limits any angular deviation that may occur when drilling into the bone.[6]

The phenomenon of greater apical deviation than coronal deviation was described by Widmann and Bale[6] and confirmed by the results of the present study. In the aforementioned studies, attention must be paid to the possible deviation values to minimize the risk of damage to the surrounding anatomical structures.

The mean apical deviation values obtained from this study were always greater than 2 mm, showing that a 3-mm minimum safety distance should be employed, particularly when a stereolithographic surgical guide is used in the mandible or without fixation screws.

The effect of smoking on the accuracy of a stereolithographic surgical guide has been infrequently investigated. In a recent study conducted by D'Haese and De Bruyn,[8] a statistically significant difference between global coronal and apical accuracy was found when smokers were compared to nonsmokers. When only global apical deviation was considered, the same authors[8] observed that, at an arbitrarily chosen 1-mm cutoff point, 65% of the implants showed an apical deviation greater than 1 mm in smokers, compared with 45% in nonsmokers, while at the 2-mm cutoff point, 10% of the implants in smokers had a higher

apical deviation, compared with almost none of the nonsmokers. The authors[8] concluded that flapless implant placement using mucosa-supported surgical guides should be implemented with care in a patient who smokes, but given the limited number of 13 drill guides included in their analysis, further research was suggested. D'Haese and De Bruyn[8] also observed that smokers had a significantly thicker mucosal biotype compared to nonsmokers, and this factor could explain why stereolithographic-guided implant placement was significantly more accurate in nonsmokers than in smokers. The authors[8] highlighted the fact that the stereolithographic surgical guide in edentulous patients should cover a maximum of supporting mucosal structures to ensure its proper positioning. Subjects who smoked showed differences in mucosal thickness compared to nonsmoking subjects, with the lower accuracy attributed to the higher degree of freedom of movement during positioning of a scanning prosthesis or surgical guide. According to D'Haese and De Bruyn,[8] this different outcome for smokers or nonsmokers is correlated to the variations in the thickness of mucosal structures, which can lead to a different resilience of the tissues.[8]

Regarding the influence of mucosal thickness on accuracy, Vasak et al[11] also showed a significant correlation between mucosa thickness at the implantation site and the amount of deviation. According to these authors, thicker mucosa affects the reproducibility of positioning as well as the stability of a purely mucosa-supported guide, regardless of whether anchoring elements are used. In agreement with the literature, the data of the present study indicate that the thicker mucosa found in smokers is related to higher deviation values. However, because the difference in the angular deviation between smokers and nonsmokers was not statistically significant in this study or in any of the literature, the higher deviation values could be explained by the increased distance between the bottom of the tube of the surgical guide and the entry point, rather than the resilience of the mucosa itself or a procedure-related error.[14] Indeed, if the angular deviation is the same in both cases, coronal deviation is directly proportional to mucosa thickness (because of the increased distance between the bottom of the guide tube and the entry point of the surgical bur at the alveolar ridge), whereas apical deviation is dependent on both mucosal thickness and the length of the implant (Fig 9).

Although angular deviation is not the only parameter to consider when evaluating the accuracy of a system (product- or procedure-related),[14] the evidence of higher global apical deviations in smokers should be taken into account during implant planning to prevent damage to the surrounding anatomical structures.

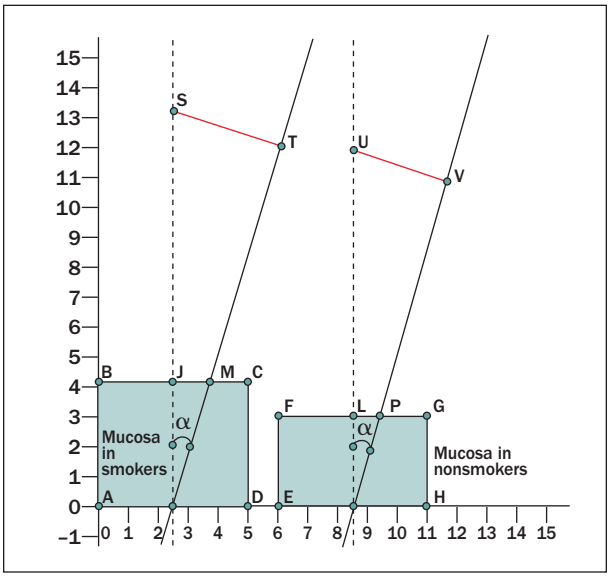

Fig 9 ABCD = Mucosal thickness in smokers; EFGH = mucosal thickness in nonsmokers; JM = global coronal deviation in smokers; ST = global apical deviation in smokers; LP = global coronal deviation in nonsmokers; UV = global apical deviation in nonsmokers. α = angular deviation.

CONCLUSIONS

Surgeons need to be aware that the accuracy of implant insertion using a mucosa-supported stereolithographic surgical guide in completely edentulous patients is influenced by variables such as the surgical technique (with a surgical guide fixed vs unfixed), the arch that supports the guide (maxilla or mandible), and the smoking habit of the subject. The results of the present study showed a high level of accuracy when fixed mucosa-supported stereolithographic surgical guides were used in the maxilla. This is most likely attributable to the fact that fixation screws and greater surface support reduce any possible displacement of the guide during surgery.

The use of stereolithographic surgical guides can simplify the treatment of complex clinical cases, but the surgeon should be aware of the possible linear and angular deviations of the system to be employed to determine the possible variations and thus better assess the safety distance required for flapless surgery. Mucosal thickness affects accuracy, resulting in a statistically significant correlation between mucosa thickness and the degree of global coronal and global apical deviations of the implant that does not arise from errors in the positioning of the surgical guide. The level of accuracy is lower in subjects who smoke because of their thicker oral mucosa. The authors use and suggest a minimum safe distance of 3 mm to avoid damage to the surrounding anatomical structures. Further studies of the accuracy of virtual vs actual implant positions

are needed to refine both the procedure and the system to better define the margin of error and therefore determine the definitive safety zone required.

ACKNOWLEDGMENTS

The authors would like to thank Dr Rossella Cappabianca, a sociologist specializing in the methodology of social research, for assistance in statistical analysis. The authors gratefully acknowledge the reviewers and associate editors of *JOMI* for the help offered in editing. Finally, the authors would like to thank IMPLADENT for technological support and for supplying the dental implants used in the study. The authors reported no conflicts of interest related to this study.

REFERENCES

1. Schneider D, Marquardt P, Zwahlen M, Jung RE. A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry. Clin Oral Implants Res 2009;20:73–86.
2. Jung RE, Schneider D, Ganeles J, et al. Computer technology applications in surgical implant dentistry: A systematic review. Int J Oral Maxillofac Implants 2009;24:92–109.
3. Nickenig HJ, Eitner S, Rothamel D, Wichmann M, Zöller JE. Possibilities and limitations of implant placement by virtual planning data and surgical guide templates. Int J Comput Dent 2012;15:9–21.
4. Farley NE, Kennedy K, McGlumphy EA, Clelland NL. Split-mouth comparison of the accuracy of computer-generated and conventional surgical guides. Int J Oral Maxillofac Implants 2013;28:563–572.
5. Eggers G, Patellis E, Mühling J. Accuracy of template-based dental implant placement. Int J Oral Maxillofac Implants 2009;24:447–454.
6. Widmann G, Bale JR. Accuracy in computer-aided implant surgery—A review. Int J Oral Maxillofac Implants 2006;21:305–313.
7. Çehreli MC, Aslan Y, Sahin S. Bilaminar dual-purpose stent for placement of dental implants. J Prosthet Dent 2000;84:55–58.
8. D'Haese J, De Bruyn H. Effect of smoking habits on accuracy of implant placement using mucosally supported stereolithographic surgical guides. Clin Implant Dent Relat Res 2013;15:402–411.
9. Cassetta M, Stefanelli LV, Giansanti M, Calasso S. Accuracy of implant placement with a stereolithographic surgical template. Int J Oral Maxillofac Implants 2012;27:655–663.
10. Cassetta M, Giansanti M, Di Mambro A, Calasso S, Barbato E. Accuracy of two stereolithographic surgical templates: A retrospective study. Clin Implant Dent Relat Res 2013;15:448–459.
11. Vasak C, Watzek G, Gahleitner A, Strbac G, Schemper M, Zechner W. Computed tomography-based evaluation of template (Nobel-Guide)–guided implant positions: A prospective radiological study. Clin Oral Implants Res 2011;22:1157–1163.
12. Cassetta M, Di Mambro A, Giansanti M, Stefanelli LV, Barbato E. Is it possible to improve the accuracy of implants inserted with a stereolithographic surgical guide by reducing the tolerance between mechanical components? Int J Oral Maxillofac Surg 2013;42:887–890.
13. Arisan V, Karabuda ZC, Özdemir T. Accuracy of two stereolithographic guide system for computer-aided implant placement: A computed tomography-based clinical comparative study. J Periodontol 2010;81:43–51.
14. D'Haese J, Van De Velde T, Elaut L, De Bruyn H. A prospective study on the accuracy of mucosally supported stereolithographic surgical guides in fully edentulous maxillae. Clin Implant Dent Relat Res 2012;14:293–303.