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A retrospective study of the accuracy of template-guided versus freehand implant placement: A nonradiologic method

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Objective. The aim of this retrospective case study was to evaluate implant placement accuracy in inexperienced clinicians with use of a surgical guide template vs the freehand method for preoperatively planned implant position.

Study Design. Oral implant therapy was performed by inexperienced dental practitioners (<20 implants placed) on eligible patients after cone beam computer tomography (CBCT)−based software planning. Two patients' groups were formed according to the surgical technique: guided and freehand implant placement. The casts used for the fabrication of reconstructions were scanned by using a 3-dimensional (3D) laser scanner, the implant positions were superimposed with preoperative planning data, and the 3D deviations were calculated.

Results. Twenty adult patients were included in this retrospective study (20 guided and 21 freehand implant placements). Mean calculated deviations with use of a surgical guide template were significantly lower compared with those of the freehand method with regard to angulation ($P = .002$), apical position ($P = .002$), and basal position ($P = .012$). No significant differences in implant placement accuracy were detected between the groups according to the implant position (premolars/molars; upper jaw/lower jaw) ($P > .05$).

Conclusions. Computer-aided planning and the use of surgical guides in accordance with CBCT images may help inexperienced clinicians to place implants with high accuracy. (Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:220−226)

In recent decades, implantology has established itself as a successful technique not only for the reconstruction of the masticatory system but also for aesthetics, and it has significantly improved the quality of life of patients.[1] In 2007, Chee and Jivraj[2] described and classified complications that can arise in preprosthetic surgery and implant-supported restorations. Among the most frequent mistakes, these authors mentioned incorrect positioning with an incidence greater than 10%.[2] Such mistakes can be investigated and quantified through postoperative radiologic analysis or by using an intraoral scan technique as part of a process that evaluates positioning.[3-7]

When left uncorrected, incorrect positioning can lead to biologic and prosthetic complications and, thus, to a mechanical overload of implants. This can result in fracture of the abutment screw and, in severe cases, of the implant itself.[2] This problem can be resolved by preoperative planning, wherein the exact number and position of the implants are determined in terms of the form and size of the final prosthetic construction. This should lead to an outcome that is perfect in terms of prosthetics and aesthetics.[2,8,9]

Studies in this field have already shown that computerized surgery represents a precise method for placing implants according to the guidelines of implantology, avoiding damage to important anatomic structures, such as the inferior alveolar nerve, the maxillary sinus, or adjacent teeth, and, in some cases, avoiding further bone augmentations with the additional risk of complications and the prolongation of therapy for approximately 4 months.[10-15]

The use of a surgical guide template showed significantly more precise results compared with implantations without an insertion aid.[16,17]

There is a mistaken impression that surgery of this kind can be carried out even by inexperienced clinicians because of the systematic simplicity of the surgical steps, made possible by the sleeve-in-sleeve concept. Studies have shown, however, that the level of experience of the clinician is of particular importance for the accuracy of implant placement.[9,18,19] The superiority of surgical templates over nonguided methods in terms of accuracy has been clearly shown.[16,17,20] However, one must consider that the participants in all these studies were experienced clinicians. Current literature does not answer the question as to whether the superiority of guided surgery is also present it is performed by inexperienced clinicians.

The purpose of this study was to examine whether the accuracy of implant placement by inexperienced

Statement of Clinical Relevance

As an educational option, the use of surgical templates offers an accurate and secure method to get acquainted with the topic and to gather initial experiences.

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clinicians would be influenced by the surgical method. The null hypothesis was that there were no significant differences in the accuracy of implant placement between the guided or the nonguided methods in terms of the angulation, basal position, and apical position, compared with preoperative implant planning.

MATERIAL AND METHODS

Study design and sample

To address the research purpose, the investigators designed and implemented a retrospective case study. Approval from the Lower Austrian committee of ethics was obtained for our study (GS1-EK-4/372-2016).

The study population was composed of patients presenting at the University Clinic for dental implant treatment between April 2015 and May 2016. Inclusion criteria comprised the use of coDiagnostiX preoperative planning software (Dental Wings, Montreal, Canada) for planning of implant positioning and the availability of master casts with analogs. Another inclusion criterion was that the clinicians were to be inexperienced. Clinicians were considered inexperienced if they had placed fewer than 20 implants.

Implant planning as well as the master casts that were included in the examination were generated for all patients in a standardized fashion, as described in the following section. For preoperative planning, the initial oral situation of the patients was recorded by means of master casts and cone beam computed tomography (CBCT; Orthophos XG 3-D; Dentsply Sirona; York, PA). In addition, a 3D data set was generated in stereolithography format with scanning the master casts by using laser triangulation (D800; 3 Shape, Copenhagen, Denmark). CBCT data and the 3D data set of the master casts were then fed into the coDiagnostiX 9.5 planning software (Dental Wings, Montreal, Canada).

In accordance with the principles of backward planning and to simulate the final prosthetic restoration, virtual dental crowns were prepared in terms of form, size, and position to perfectly restore the dental arch. Implants were then virtually placed according to the final position of the prosthetic crown.

The following criteria were taken into account for optimal implant positioning: a circumferential bone level of at least 1 mm, a distance of at least 1.5 mm between the implant and adjacent teeth, an implant−implant distance of at least 3 mm, and a distance of at least 2 mm to nearby neuromuscular structures, such as the inferior alveolar nerve and the maxillary sinus.[21]

According to the predictor variable, the patients were divided in 2 groups. In the first group, implants were placed in a half-guided fashion. That is, with the sleeve-in-sleeve system, different guide spoons with increasing internal diameters were placed inside the polymerized sleeves, which were inserted into the surgical template beforehand to prepare the implant bed in a template-guided fashion. In this case, the standardized preoperative planning was transferred to a surgical template that was then printed in 3D (Varseo; BEGO GmbH & Co. KG, Bremen, Germany). From a validated template polymer (VarseoWax Surgical Guide; BEGO GmbH & Co. KG, Bremen, Germany). In group 2, the implants were placed in a freehand fashion.

Furthermore, the influence of the implant position (premolar/molar; upper jaw/lower jaw) on the placement accuracy was evaluated.

Data collection methods

After the healing of the implant sites and the formation of the emergence profile, impression posts were screwed onto the implants, and an impression of the complete dental arch was taken. The impression was taken by applying the open tray impression technique and using a vinyl polyether silicone impression material (EXA'lence; GC Europe, Leuven, Belgium) and a customized impression tray.

The implant position was secured by using impression posts, and implant analogs were then basally screwed onto the impression posts. The impressions were then filled with plaster to obtain master casts for the construction of functional and aesthetic restorations. For evaluation of the postoperative position, scan posts were screwed onto the implant analogs to generate a 3D data set by using a model scanner (D800; 3 Shape, Copenhagen, Denmark).

The 3D data of the master cast were then superimposed onto the preoperative implant planning data by a treatment evaluation tool that is found in the planning software coDiagnostiX 9.5 (Dental Wings, Montreal, Canada). The automated superimposition was initialized by a manual selection of common landmarks that occur in the 3D data set of the master cast as well as the segmentation model of the preoperative CBCT (Figure 1). In coDiagnostiX 9.5 (Dental Wings, Montreal, Canada), the implant was then connected to the scan post to simulate the postoperative implant position (Figure 2).

As primary outcome variables in this study the differences between the planned and the achieved positions of the implant were defined. They were calculated on the basis of the deviation in angulation, the level of the implant shoulder (basal) in relation to the x-axis, y-axis, and z-axis, and the position of tip of the implant (apical) (Figure 3). The z-axis was defined by the axis of the planned implant and described deviations in the craniocaudal dimension. The y-axis was in an orthogonal position to the z-axis and showed

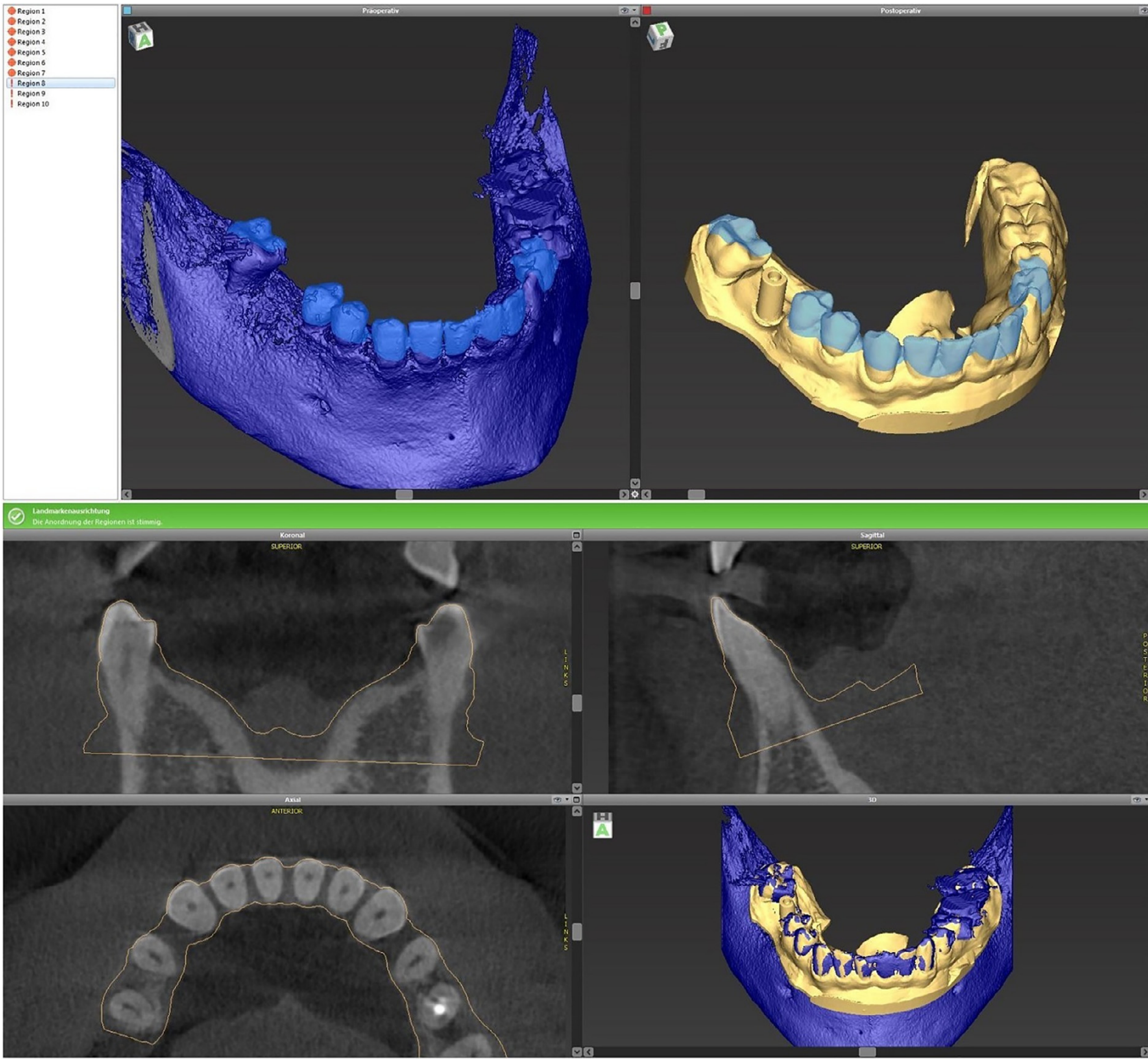

Fig. 1. Superimposition of the segmentation model of the cone beam computed tomography (CBCT) with the 3-dimensional data set of the master cast by a manual selection of common landmarks.

horizontal deviation in the orovestibular dimension. The x-axis was perpendicular to both other axes and thus showed deviations in the mesiodistal dimension. Angular deviation, the sum of deviations in relation to the axes, and the 3D drift ($\sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2)}$) were then analyzed.

Fig. 2. Identification of the scan posts was carried out by clicking on the upper edge of the scan post.

Statistical analysis

The statistical analysis was carried out with SPSS version 23 (SPSS Inc., Chicago, IL). The distribution of the data was examined with the Shapiro-Wilk test to confirm normal distribution. The data with existent normal distribution were examined with the *t* test, and data with nonexistent normal distribution were analyzed with the Mann-Whitney test. *P* values of $\leq$ .05 were considered statistically significant.

RESULTS

A total of 41 implants from 20 patients were observed for the study. The patients' characteristics are summarized in Table I. Figure 4 and Table II show the differences between preoperative planning and postoperative positions of implants.

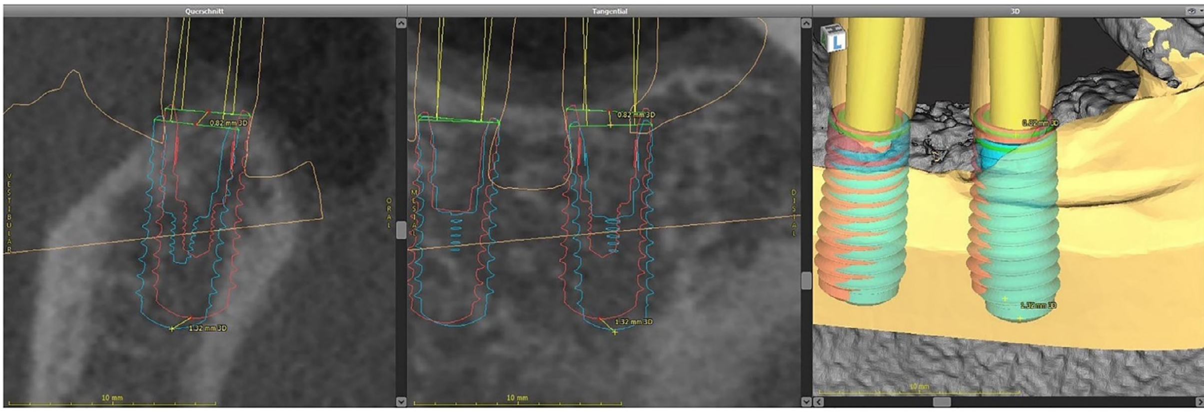

Fig. 3. Treatment evaluation showing the deviation between the planned *(blue)* and achieved *(red)* implant position.

Guided implant placement produced significantly smaller deviations compared with the freehand method in terms of the apical ($P = .002$) and basal ($P = .012$) positions, as well as angulation ($P = .002$). Within the groups, no significant differences according to the implant position (premolars/molars; upper jaw/lower jaw) could be detected ($P > .05$).

DISCUSSION

In this retrospective case study, implant placement accuracy was evaluated for the guided technique vs the freehand placement technique, as used by inexperienced clinicians. A nonradiologic method was utilized for comparison of the implant position with preoperative 3D planing. Our working hypothesis could be rejected. There were significant differences in implant placement accuracy for all measured parameters between the groups, with higher accuracy demonstrated for the surgical template−guided group.

Mistakes in the positioning of the implant are one of the main errors in implant dentistry.[2] The precise and prosthetically functional placement of the implant is of utmost importance if reliable sustainability is to be maintained.[22] It is not enough to perform preoperative planning. A good outcome can only be obtained by precisely transferring preoperative virtual planning to the clinical situation. Nowadays, surgeons have a choice between operating by using a guided method or a nonguided method to transfer information gathered before the operation to a clinical situation.[23]

By comparison, the conventional nonguided method is the most inaccurate.[9] Nickenig et al. and Arisan et al. showed that implant placement after preoperative planning with the help of CBCT and the application of a surgical template is significantly more accurate compared with freehand implant placement.[16,17] When operating in a nonguided manner in a freehand situation or in an edentulous patient, the clinician's orientation is dependent on certain anatomic structures.[17]

Several studies have shown that the use of previously planned surgical templates is an accurate method.[8,9,24-30] According to all of the studies we identified in the literature search, the application of a surgical template leads to lower deviations compared with the nonguided method.[7,16,17,20] Additionally, fewer errors in positioning and higher predictability were found with the guided method.[7,20]

In contrast to the findings of other studies that describe the accuracy of template-supported implant dentistry in humans, our findings showed differences in mean deviations. Our results show greater inaccuracy compared with the study of Van Assche et al.[30] with a mean deviation in angulation of 2.2 ± 1.1 degrees, 0.6 mm ± 0.3 mm at the level of the implant shoulder, and 0.9 mm ± 0.4 mm at the level of the tip of the implant. Lee et al. found a similar mean deviation of 3.8 ± 3.24 degrees in angulation, 1.09 mm ± 1.1 mm at the implant shoulder, and 1.56 mm ± 1.48 mm at the implant tip.[26] Schneider et al. showed in a systematic review a mean deviation in angulation of 5.73 (95% confidence interval [CI] 3.96−7.49 degrees), 1.16 mm (95% CI 0.92−1.39 mm) at the implant shoulder, and 1.95 mm (95% CI 1.33−2.58 mm) at the implant tip,[29] which is within the obtained results.

Possible reasons for the differences in the deviations between the present study and the above-mentioned studies could be the technique applied and the level of

Table I. Study participants and implant position

	% Female	*Age*	*Upper premolars*	*Lower premolars*	*Upper molars*	*Lower molars*
Guided (n = 8)	50%	56.2	5	3	2	10
Freehand (n = 12)	58.3%	57.1	5	2	3	11

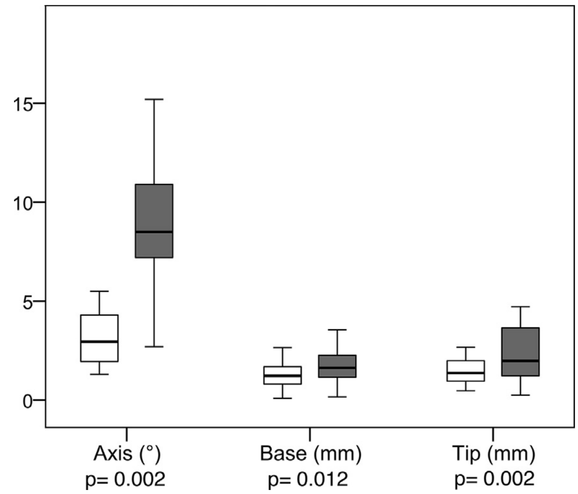

Fig. 4. Boxplots of the measured deviations for the guided (white) and freehand group (grey).

experience of the clinicians. It has frequently been reported that the level of experience influences the outcome of treatment. Results from the study by Cho et al. support this statement.[31] A prospective, multicentric clinical study with 2641 placed implants demonstrated a certain learning curve. Less experienced clinicians failed more frequently compared with experienced clinicians.[32] In 2008, Van de Velde observed how the final position achieved by students differed significantly from the one that was achieved by specialists.[33] By contrast, Kohavi et al. found that clinical experience does not correlate with treatment outcome. However, in this study, the inexperienced clinicians were accompanied by faculty members.[34]

In these aforementioned studies, all implants were placed in a fully guided manner, which meant that surgical templates were used while completing the drilling protocol as well as during the final implant insertion. A significant difference has been shown in the literature between fully guided and half-guided implant placements. Park et al. showed that a higher accuracy in implant positioning was achieved when using a surgical template for implant insertion than by means of freehand implant insertion.[35] Kühl et al. confirmed this finding and added that bone density influenced the accuracy of implant placement during freehand implant insertion after a fully guided drilling protocol was carried out for implant bed preparation.[36] In clinical practice, complex cases are usually treated with the help of surgical templates, whereas less complex cases are usually treated by using the nonguided method. More inaccuracies can be found in complex cases.

The evaluation of accuracy in terms of the transfer of information from preoperative planning to the clinical situation was usually carried out by superimposing the preoperative planning scans onto the postoperative computed tomography scans.[5] Nickenig et al. showed an alternative method that reduces exposure to radiation, that is, by obtaining images of master casts containing implant analogs through CBCT.[3] The method of obtaining the postoperative implant position used in this study is comparable with the method used by Stoetzer et al. and von See et al.[6,37] Scan bodies were used to obtain information about the postoperative position. For this reason, intraoral scanning was carried out, and it additionally reduced the radiation exposure of the patient in the process of evaluation of the implant position.[6,37]

In the present study, the method of scanning the master cast analogs with screwed-on scan bodies replaced the intramural scan. The manufacturing of master casts and the scanning process can result in errors of transfer. Conventional impressions are subject to shrinking, an inhomogeneous surface in terms of the impression compound, detachment from the impression tray, and expansion of the plaster used.[38] The accuracy of the digitalization of the clinical situation was examined by Guth et al.[39] in a study comparing a direct intraoral scan, the digitalization of the impression, and an indirect digitalization of the master cast to the reference model. They concluded that direct digitalization (15 μm ± 6 μm) is significantly more accurate than the digitalized impression (23 μm ± 9 μm) and the indirect method (36 μm ± 7 μm).[39]

Other sources of error include the CBCT scan being the basis for the planning of the implant position, which reportedly has a deviation of approximately 0.5 mm preoperatively for the Orthophos XG 3-D CBCT (Dentsply Sirona, York, PA), which was also used in our study.[40,41]

Standard deviation is a statistical tool used to measure the variations that exist in a process and can be regarded as a measure of precision. The standard deviation values for the deviations in all assessed parameters for group 1 were lower, at least by factor 2. Thus, the use of template-based surgical guide increased the predictability of the implant position and, thus, the safety of the treatment. It has been shown that the experience level of the operator placing the implants

Table II. Mean deviations for angulation, basal position, and apical position (standard deviations)

	Angulation (degrees)	*Basal position (mm)*	*Apical position (mm)*
Guided (n = 8)	3.4 ± 1.7	1.26. ± 0.68	1.47 ± 0.67
Freehand (n = 12)	9.7 ± 4.4	2.12 ± 1.28	2.92 ± 1.91

contributes to the accuracy of implant placement, even when a surgical template is been used.[19] In the literature, the angle deviation of 3 degrees is described as tolerable in terms of preservation of anatomic structures and loosening of implant abutment and passive fit.[42-44] This requirement could not be met for freehand implant placement in this study. From this point of view, the use of template-based surgical guides can be strongly recommended to clinicians with limited surgical experience.

CONCLUSIONS

Within the limitations of our study, the following conclusions can be drawn: the dental navigation system used in this retrospective study had significantly higher accuracy and precision compared with freehand implantation with regard to angulation and basal and apical implant positions compared with preoperative planning. The use of surgical templates during implantation procedures can be highly recommended, especially to inexperienced clinicians, to increase the predictability and safety of the treatment.

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