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Comparison of the Accuracy of Computer-Guided Implant Placement Between Native Bone and Extraction Socket

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Abstract

Background: The aim of this study was to evaluate the accuracy of implant placement using static guide surgery. Two methods of were compared: Implant placement in native bone and in post-extraction site.

Methods: 47 implants were placed with static surgical template using a flapless technique. Patients were divided into two groups: Group 1 was made by 29 implants placed in extraction socket while group 2 was made by 18 implants placed in native bone. Accuracy of implant placement was evaluated by CBCT superimposition protocol.

Results: The study showed differences between two methods of implant placement in two parameters considered. The average real deviation detected at the implant platform level is 1.00 ± 0.91 mm for post-extraction site and 0.49 ± 0.48 mm for native bone (P=0.01). The average angular deviation detected at implant level is 21.94° ± 36.80° for post-extraction sites and 12.80° ± 11.71° for native bone (P=0.006).

There were not statistically differences between two methods for 7 parameters left.

Conclusion: The present study showed that implant placement in native bone is more accurate than in post-extraction sites using a static surgical template.

Keywords: Accuracy; Computer-guided surgery; Implant-guided surgery; Extraction sockets

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Introduction

The introduction of tissue engineering and modern digital technologies have allowed for the development of innovative techniques in dentistry. Specifically, with the discovery of Computerized Tomography (CBCT) along with modern 3D virtual scanning software, and with the alignment of CBCT and scanning, it is possible to pre-plan the intervention by creating a surgical guide that allows for the passage of drills through it into the previously defined position [1,2].

The traditional method for implant insertion involves preparing a full-thickness flap, followed by implant insertion and closure of the flap for primary intention [3]. Guided static surgery is often performed with flapless method. The reason is that by positioning the implant without preparing a full-thickness flap, there is less invasive surgery with reduced bleeding, swelling, hematoma, and systemic inflammation, resulting in reduced postoperative pain and, therefore, a lower intake of analgesic drugs [3,4].

The advent of computer-guided surgery has also allowed for increased accuracy in implant placement and less surgical invasiveness [2,5]. Implants are inserted after computer programming, which allows for the evaluation of noble structures such as vessels and nerves and future prosthetic emergencies [2].

The accuracy of the surgical guide depends on the precision of the CBCT and 3D scanning execution [5,6]. Excellent CBCT and scanning images, in fact, allow for the maximum precision in constructing the surgical template.

However, errors can be introduced due to the precision of creating the surgical template and its placement. In addition, there may be other errors due to the gap present between the surgical guide sleeve [5].

Despite being built with precision, surgery may not be accurate due to reasons such as poor-quality bone tissue, swollen mucosa due to anesthesia, thin mucosa, or bone dehiscence's that could compromise the correct positioning of the template, especially if it is supported by mucosa (reference can be added on mucosal resilience) [5,7].

Guided surgery has allowed for a considerable improvement in the accuracy of post-extraction implant insertion compared to the traditional method [8]. However, even by inserting the implant through the surgical template, in post-extraction sites, drill tends to follow the path created by the alveolus, introducing errors in the average deviation and final angular deviation of the implant position from the one programmed on the computer [9].

The objective of this study is to compare the accuracy of computer-guided flapless approach surgery in post-extraction and native bone procedures using a CBCT superimposition protocol.

Materials and Methods

Study design

The study was designed in accordance with the ethical principles for medical research involving human subjects of the World Medical Association Declaration of Helsinki and is identified as a prospective clinical study to compare the accuracy of implant placement in post-extraction site and native bone using guided surgery technique.

Patients

All patients included in this study were adults, selected between October 2018 and May 2020. The patients included in the study had partial or total edentulism, sufficient height for implant placement, sufficient thickness of the bone crest for implant placement, informed consent and acceptance of the implant-prosthetic treatment plan and were over 18 years of age.

Patients were excluded from the study if they had insufficient oral hygiene, smoked, abused alcohol or drugs, had acute dental or stomatological infections, were ASA 4 or 5, had remote or recent radiotherapy in the oro-maxillo-facial area, recent chemotherapy, recent bisphosphonate therapy, were pregnant, required bone grafting, had uncontrolled diabetes, or had limited mouth opening (inability to use surgical guides and drills).

Planning procedure

For this study, design software (Navimax®, Biomax) and digital workflow were used for the clinical case study and production of surgical guides for both post-extraction sites and native bone, with support either on the mucosal or dental tissue.

After collecting the patient's medical history, impressions of both dental arches were taken using preformed steel spoons and alginate for the development of plaster models in the dental laboratory.

The arch impressions were optically scanned using a laboratory scanner to obtain a digital file in stl. format.

The patient was provided with a customized radiographic marker (Navibite®, Biomax) based on their occlusion, which they wore during the CBCT acquisition phase (Figure 1).

Next, the patients underwent CBCT (Newtom) with a standard setting of 110 kV, 70 mAs. Files were exported in DICOM format with 0.3 mm sections and 512 × 512 pixels.

The radiographic marker used for the CBCT was recognized by the software, enabling the coupling of the DICOM file with the STL file obtained from the impression scan.

Subsequently, the surgical design phase began. Using the software, implant placement was designed in the most favorable three-dimensional position considering the amount of available bone, proximity to any vital structures, and primarily for future prosthetic emergence.

Once the design phase was complete, the file was sent to the company (Biomax), which produced and sent the surgical guide to the clinician based on the design executed (Figure 2).

Surgical procedure

All surgical procedures were performed by the same operator. The surgical procedure involved implants placement (T3, 3i) using a surgical template with Peek bushings for mucosal or dental support depending on the case, but always with a flapless technique. In only four cases, tooth extractions were necessary.

Patients were prescribed antibiotics and rinsed with a

Figure 1: A radiological guide with aid of silicone index secured by opposing arch.

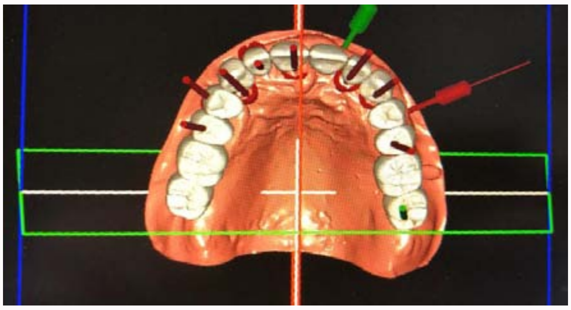


Figure 2: Virtual planning of implant surgery.

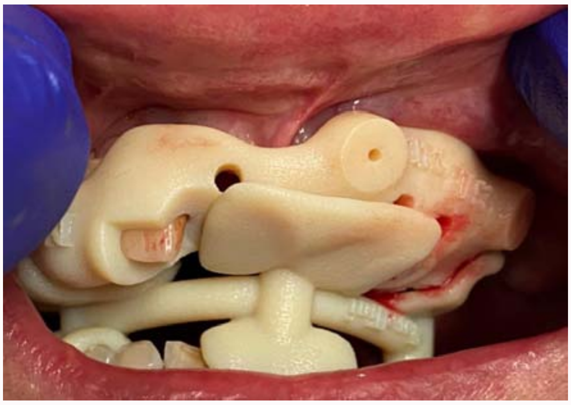


Figure 3: Surgical template with stabilizer positioned inside patient's mouth.

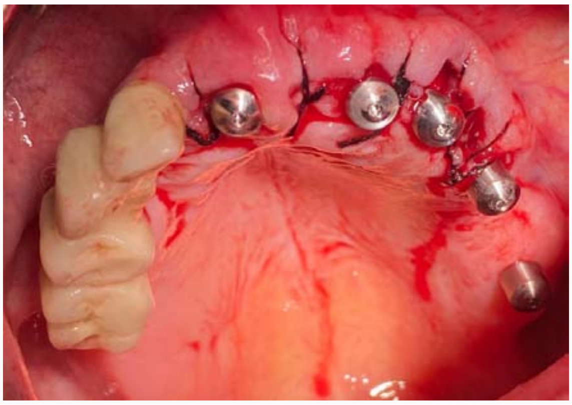


Figure 4: Implants in position, with cover screws placed.

chlorhexidine gluconate 0.2 mg/ml mouthwash for one minute before the surgical procedure.

During the surgical procedure, after preparing the patient, local anesthesia with 1:100,000 adrenaline was infiltrated, followed by the application of the surgical template.

For post-extraction cases, two surgical guides were used. The first template was inserted to support the teeth, allowing the insertion of pins that would be used to fit the second template once the teeth were extracted. Subsequently, the teeth were extracted with the least possible surgical trauma.

The second surgical template, supported by the mucosa, was then applied with the help of the antagonist arch (Stabilizer®, Biomax). Once the correct fit was verified, the guide pins were reinserted for fixation.

The use of surgical pins reduces the clinical stress associated with the safety of template positioning, thanks to the invitation holes made prior to tooth extraction. In addition, the use of pins allows for complete fixation of the guide, which therefore cannot have any movement during the surgical procedure (Figure 3).

Access to the bone tissue was obtained using a mucotomy, followed by preparation of the implant site using drills. The surgical procedure was performed under continuous irrigation with sterile saline solution.

Non-absorbable sutures were applied where necessary. Postoperative information and instructions regarding oral hygiene were given to the patient (Figure 4).

Accuracy evaluation

The Superimposition Standard protocol was used to evaluate the accuracy of placed implants. Approximately 6 months after the surgery, a CBCT was performed using the same parameters as the preoperative one. The DICOM files were imported into the software, and the geometric shape of the implant was overlaid onto the implant volume visible in the CBCT. This allowed for the determination of the postoperative implant position, and the STL file was saved. The file was then imported into Geomagic Studio (3D System), an engineering software, and an algorithm for coupling two 3D models was used to match the pre- and post-surgical models and calculate the alignment error. Additionally, a second software, Rhinoceros, was used to measure deviations in the three planes of space, considering the implant center and apex, as well as angular deviations. After collecting the data in Excel, the mean values of the different linear and angular deviations were calculated, along with their respective standard deviations. Finally, the Student's t-test was used to verify the statistical significance of the differences in the means (Figure 5).

Statistical analysis

47 implants were analyzed, 29 of which were in post-extraction sites and 18 in native bone.

Descriptive statistics were used to evaluate the accuracy of implant placement and the difference between the two techniques.

Implant deviation was analyzed in the 3 planes of space, using the terminology commonly used in dentistry, defined as errors in the

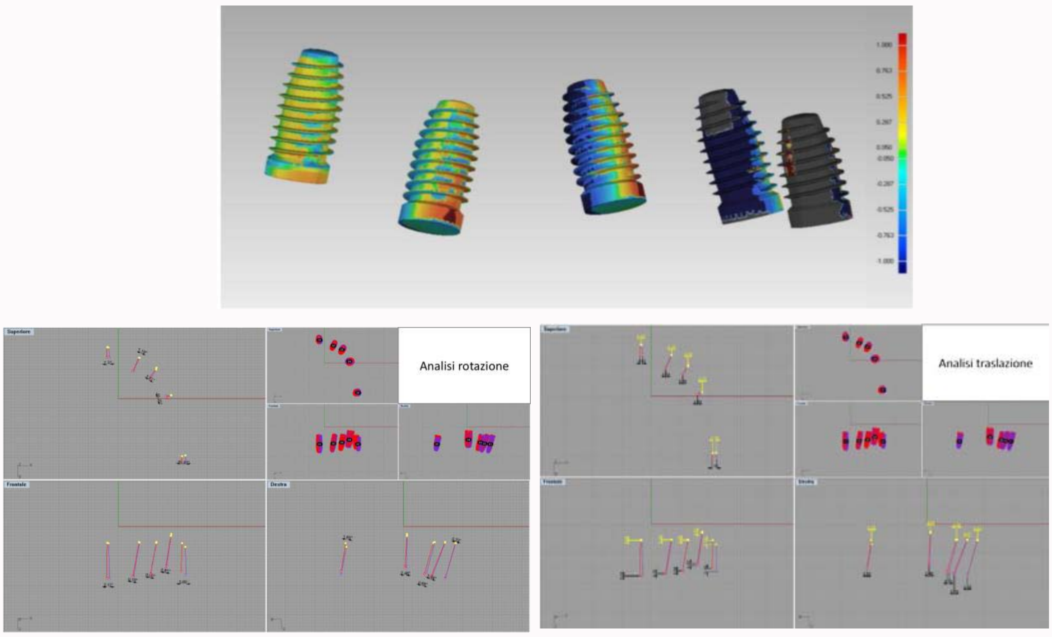


Figure 5: Overlapping of virtual and postoperative position of implants in virtual environment allowing for deviation measurements.

Mesio-Distal (M-D), Apico-Coronal (A-C), Vestibulo-Palatal (V-P) dimensions.

A 95% confidence interval was used for all analyses.

To verify the significance of the difference in mean angular deviations between post-extraction implants and non-post-extraction implants, the student's t-test was used. A probability level of 0.05 (5%) was chosen, and this probability (called the P-value) is a quantitative estimate of the probability that the observed differences are due to chance.

Results

No implant showed signs of infection or failure during finalization. Using the standard CBCT superimposition protocol, the mean deviation between the ideal implant position and the post-extractive surgical position was found to be 0.413103448275862 ± 0.329441569810405 mm at the implant entry point and 0.607241379310345 ± 0.403381367867834 mm at the apical point of the implant in the mesiodistal direction; 0.812068965517241 ± 0.649043749178132 mm at the implant entry point and 0.759620689655172 ± 0.654074677471823 mm at the apex in the apicocoronal direction; 0.561724137931034 ± 0.549662682050918 mm at the implant entry point and 1.00441379310345 ± 0.906761935728233 mm at the apex in the palato-vestibular direction.

The mean deviation between the ideal implant position and the post-surgical position in non-extractive cases was 0.403684210526316 ± 0.280222342798551 mm at the implant entry point and 0.677 ± 0.619774062775209 mm at the apex in the mesiodistal direction; 0.555263157894737 ± 0.537539336245912 mm at the implant entry point and 0.526842105263158 ± 0.454386676149277 mm at the apex in the apicocoronal direction; 0.463157894736842 ± 0.53635656290671 mm at the implant entry point and 0.49 ± 0.476981248175556 mm at the apex in the palato-vestibular direction.

Regarding the angulation in guided implant surgery, using the standard superimposition protocol, the mean deviation was 21.9413793103448 ± 36.7972890422124 degrees in the mesiodistal plane in post-extractive implant surgery; 1.60206896551724 ± 1.13487164490799 degrees in the apicocoronal plane, and 2.8551724137931 ± 2.28304639294572 degrees in the palate-vestibular plane. In non-extractive guided implant surgery, the mean deviation in angulation was 12.7952631578947 ± 11.7064010829883 degrees in the mesiodistal plane, 3.28052631578947 ± 2.27400887735053 degrees in the apicocoronal plane, and 2.40421052631579 ± 2.07959749254373 degrees in the palato-vestibular plane.

To verify the significance of the difference in mean deviations and angles between post-extractive and non-extractive implants, the student's t-test was used. A probability level of 0.05 (5%) was chosen, which is a quantitative estimate of the probability that the observed differences are due to chance. Specifically, the P-value is the probability of obtaining a result as extreme or more extreme than the observed one if the difference is entirely due to sampling variability, assuming that the initial null hypothesis is true. As P is a probability, it can only take values between 0 and 1. A P-value that tends to 0 indicates a low probability that the observed difference can be attributed to chance.

Tables 1 and 2 show the difference in accuracy between the two different implant sites (post-extractive and native bone), reporting the mean deviations and angular deviations, respectively.

The p-value for the average deviation of the platform in the M-D, A-C, V-P directions, and the average angular deviation in the M-D and V-P directions of the apex indicates a much greater value than the chosen level of significance (α=0.05), therefore, the null hypothesis can be accepted, concluding that there are no statistically significant differences between post-extractive guided implant surgery and surgery in native bone. However, concerning the average deviation of the apex in the V-P direction and the A-C angle, the p-value is lower than the chosen level of significance, which rejects the null hypothesis. Therefore, there is a statistically significant difference between the two study groups in two spatial parameters (Graph 1, 2).

Table 1: Descriptive data reporting range of apical and coronal deviation of position of implant placed in relation of implant planned.

Position	Post-extraction	Native bone
Apex M-D	0.61 ± 0.40	0.68 ± 0.62
Platform M-D	0.41 ± 0.33	0.40 ± 0.28
Apex A-C	0.76 ± 0.65	0.53 ± 0.45
Platform A-C	0.81 ± 0.65	0,56 ± 0.54
Apex P-V	1.00 ± 0.91	0.49 ± 0.48
Platform P-V	0.56 ± 0.55	0.46 ± 0.54

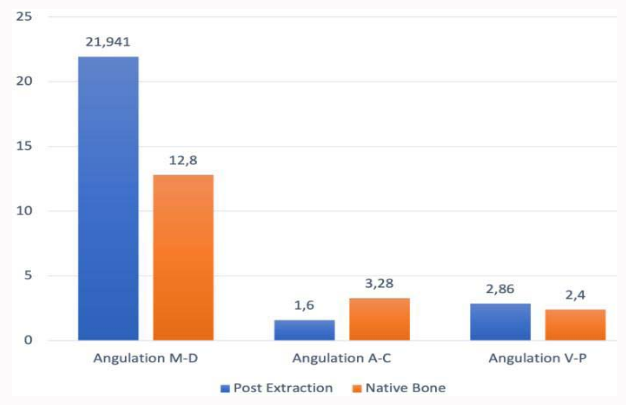
Table 2: Descriptive data reporting range of apical and coronal angular deviation of position of implant placed in relation of implant planned.

Angulation	Post extraction	Native bone
M-D	21.941 ± 36.78	12.80 ± 11.71
A-C	1.60 ± 1.13	3.28 ± 2.27
V-P	2.86 ± 2.28	2.40 ± 2.08

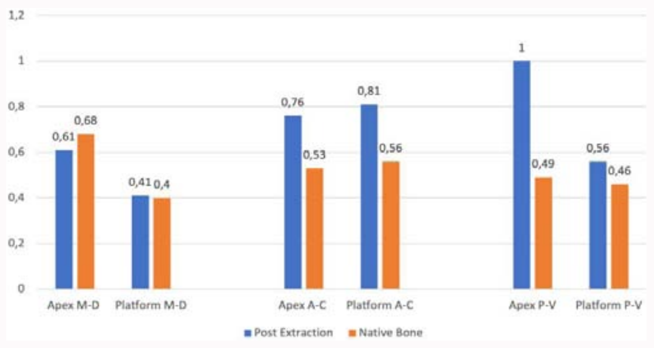
Discussion

Several recent systematic reviews have evaluated the accuracy of implant placement compared to the ideal position using the technique of guided surgery [10-12]. Errors are always present between computer design and surgical intervention. In 2018, the International Team for Implantology showed an average error of 1.2 mm at the entry point and 3.5° of angulation [6]. For this reason, they recommend maintaining a 2 mm safety margin. However, guided implantology accuracy is greater compared to freehand placement [13,14].

The introduction of CBCT in dentistry as a three-dimensional imaging tool has led to a breakthrough in this field, as it presents a



Graph 1: Graphic reporting range of apical and coronal angular deviation of position of implant placed in relation of implant planned between post-extraction and native bone.



Graph 2: Graphic reporting range of apical and coronal deviation of position of implant placed in relation of implant planned between post-extraction and native bone.

compact design, low radiation exposure, and a short scanning time [1]. CBCT is, in fact, a possible error that may be present in the workflow, as demonstrated by Pettersson et al. Patient movement during CBCT scanning can increase the implant's angular deviation error [15].

However, the technique of flapless guided surgery has increased accuracy compared to an open flap technique [11,16]. Some studies suggest that the flap may interfere with the fixation of the surgical guide due to the space requirement [16,17]. Additionally, using the flapless technique results in decreased postoperative discomfort for the patient [3,4]. However, the flapless technique is preferable only in cases where there is sufficient keratinized gingiva [18].

In this study, the data obtained are in line with those reported in the literature, with implant positioning accuracy in native bone sites comparable to those reported by Tahmaseb et al. [19], supported by guided implant surgery data reported by Vercruyssen et al. [20], and slightly inferior, at least in terms of average position deviations compared to those reported by Cassetta et al. [21]. Regarding the accuracy of implant placement in post-extraction sites, as reported by Chen et al. in 2022 [9], it is more complicated than the placement of implants in native sites because the drill tends to follow the path left by the recently extracted tooth, as supported by the study of Van Assche and Ouirynen in 2012 [12]. The above is in line with the data obtained in this study, which demonstrate better accuracy in the group of implants in native bone sites compared to post-extraction sites. In particular, the student t-test revealed statistically significant differences between the two groups in the position of the apex regarding the mean deviation in the vestibulo-palatal direction and the angular deviation in the mesiodistal direction with p-values of 0.015 and 0.006, respectively. However, the statistical test also indicates that there is no significant difference for the other 7 parameters considered. For this reason, the operator is advised to move the drill while maintaining the most parallel direction possible to the circumferential walls of the burs when the drill comes into contact with alveolar bone.

In average positional and angular deviations of implants placed with guided surgery, cumulative and independent errors that occurred in the pre- and post-operative phase should be taken into account. Therefore, during impression taking (alginate) and plaster casting, optical scanning in the laboratory, CBCT execution, and the operator's experience [22].

Conclusion

From the statistical analysis of the deviations in position and angulation between the group of implants placed in immediate post-extraction sockets and the group of implants placed in native bone, there are statistically significant differences, particularly in the deviation of the apex in the vestibulo-palatal/lingual direction and in the apico-coronal angle. These differences should be taken into account by the clinician during the intervention, maintaining a safety distance of 2 mm from vital structures to avoid complications.

Despite these data, the differences between the two groups do not preclude the successful outcome of computer-guided implant insertion. The method is particularly safe and accurate, but it is important to be aware that it is a surgical system sensitive to the presence of cumulative errors during different procedures.

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