



Article

The Freehand Technique: The Ability of the Human Eye to Identify Implant Sites on the Patient

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Abstract: In implantology, among the key choices, to obtain predictable results, it is essential to establish, using cone beam computed tomography (CBCT), the bone site and where to insert the implants; during the surgical phase, these sites must be identified on the oral mucosa. Surgical templates are a valid aid, especially in complex cases which require the insertion of more than three or four implants. In cases of a single implant, on the other hand, surgical guides are rarely used, and the implant is often inserted freehand; therefore, the identification of the implant site on the oral mucosa (after choosing the location on the CBCT) is more difficult. For this reason, the clinician uses the teeth in the arch as a reference. This study evaluates the ability of the human eye to identify, on the oral mucosa, where the implant collars will be positioned, the position of which has previously been chosen on the CBCT, in cases where the hands-free surgical technique (without surgical guides) is used. The verification of this precision is carried out using particular thermo-printed templates which contain radiopaque metal spheres. The results show that, in the freehand technique, it is difficult to precisely identify the implant sites (chosen via X-ray) on the mucosa, especially when they are far from natural teeth adjacent to the edentulous area. In case of monoedentulism, the freehand implant technique seems to be applicable by expert implantologists with a reduced risk of error; in fact, clinical experience helps to find the correct correspondence between the implant site chosen on the CBCT and its identification on the mucosa. The level of experience is fundamental in the clinician's decision about whether or not to use surgical guides; in fact, doctors with little experience should use surgical guides even in the simplest cases to reduce the risk of error.



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1. Introduction

In implantology, it is a priority to determine the optimal locations and angles for implant insertion. Cone beam computed tomography (CBCT) has facilitated a simplified and precise organization of surgical procedures through computerized image processing [1,2]. CBCT enables clinicians to accurately assess the maxillary or mandibular bone, aiding in the decision-making process for fixture placement.

The three-dimensional CBCT images can be imported into implant planning software where they are analyzed to ascertain bone density, the number of implants required, and their optimal positions and inclinations [3]. Additionally, Digital Imaging and Communications in Medicine (DICOM) data from computed tomography allow the production of surgical guides [4–6]. These guides streamline the clinical localization of implant sites, ensuring predictable and successful results [7–11].

Surgical guides typically incorporate holes with metal bushings aligned with the position and insertion angle of implants, guiding surgical drills to create the artificial alveolus. The utilization of surgical guides aims to provide patients with a more comfortable, less invasive, and sometimes flapless procedure, leading to shorter recovery times [12,13].

In contemporary implant planning, computer-assisted techniques introduce the “digital workflow”, streamlining the entire protocol.

However, the creation of surgical guides can be overly complex and costly, especially when considering the size of the edentulous site and the number of planned implants [14–16]. In cases where surgical guides are not used, the implants are inserted freehand after deciding on their location via CBCT. The future position of the implant screw collar on the oral mucosa remains to be identified; in the freehand technique, this localization is carried out using anatomical references (such as the residual teeth present in the arch).

For single-tooth edentulism in fact, the risk of error in identifying the implant site is minimal due to the presence of neighboring mesial and/or distal teeth. Errors become more likely as the width of the edentulous area increases, influencing precision when relying on the distance between natural teeth and the presumed implant insertion area on the mucosa [17–20].

This study evaluates the ability of the human eye to identify implant sites (previously chosen on CBCT) on the patient’s oral mucosa in various clinical conditions when the freehand technique is performed.

An experimental thermoformed template was created for each patient to evaluate the accuracy of the match between the selected area on radiography and the oral cavity.

It is essential to clarify that this study does not intend to evaluate the complete positioning of implants, including angulation. Instead, it focuses on highlighting the human eye’s ability to identify a punctiform area on edentulous mucosa, where the implant collar will be positioned, especially in cases where anatomical references, such as teeth in the arch, are distant. This feature is crucial in the freehand technique, particularly in large edentulous areas.

2. Materials and Methods

Institutional Review Board Statement. This clinical research was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the Policlinico Paolo Giaccone University of Palermo (Protocol code: # 4-19-04-23).

All patients taking part in the study read and signed a declaration of consent to participate in the research and to publish the data.

Initial study groups and eligibility criteria. From an initial pool of 84 edentulous patients, we selected 46 individuals with partial edentulism (excluding those who were completely edentulous). This subset of patients, for whom fixed prosthetic rehabilitation with either single or multiple implants (up to a maximum of three implants) was planned, underwent further scrutiny.

In cases requiring multiple implants, only those patients in whom the fixtures were planned sequentially without the interposition of natural teeth were included in the study.

Research protocol. Preliminary panoramic radiographs and alginate impressions, used to obtain plaster models, were taken for all patients. An expert implantologist, with over twenty years of clinical activity in implantology, using clinical and radiographic data (panoramic radiography) initially determined where the implants could potentially be positioned (these choices will eventually be confirmed by the CBCT). These chosen points were then marked on the plaster models using a marker.

The selection of implant sites via panoramic radiography was conducted exclusively for research purposes. The confirmation of these sites, ensuring proper clinical implant positioning, will occur later through cone beam computed tomography.

For each patient, steel spheres with a diameter of 2 mm were affixed to the diagnostic plaster models precisely at the points marked by the felt-tip pen. Thermo-printed templates, with a thickness of 0.5 mm and a soft consistency, were then created on the modified plaster models.

During the hot thermoforming process (by Ecovac Clarben), these templates seamlessly incorporated the previously positioned tiny spheres onto the plaster models (Figure 1).

Consequently, each template now features a radiopaque sphere precisely corresponding to the presumed implant site (Figure 2).



Figure 1. Example of a plaster model with two radiopaque metal spheres positioned on the presumed implant sites.



Figure 2. Example of an experimental template built on the model depicted in Figure 1 with the two radiopaque spheres incorporated.

The prepared templates were worn by the patients during the CBCT exam, allowing for the visualization of radiopaque spheres on the resulting radiographs (see Figures 3 and 4).

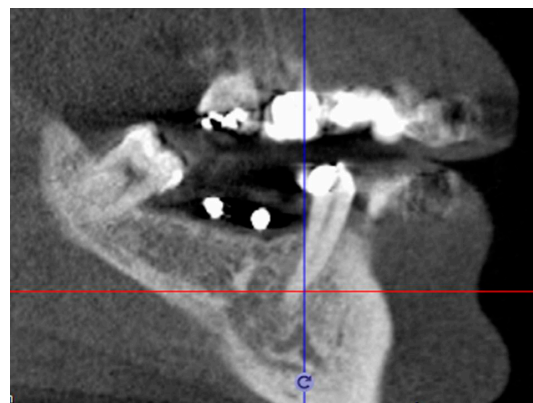


Figure 3. CBCT image taken on a patient wearing a thermoformed mask. The radiopaque metallic spheres are clearly visible.

The X-ray images distinctly show the metal spheres at the anticipated points where the fixtures could be inserted. Due to their small size, unwanted scattering effects typically caused by metallic objects were completely negligible, ensuring that the quality and readability of the X-ray exam remained unaltered. If some residual dispersion effect was present, it did not prevent the correct interpretation of the images also because the radiographic projection of the metal spheres was always not superimposed on the bone.



Figure 4. Section of CBCT, carried out on a patient wearing an experimental mask, showing a metal sphere.

Final study groups and eligibility criteria. CBCT scans for all 46 patients were examined, resulting in the selection of 23 patients whose chosen implant sites, initially identified through orthopantomography, were subsequently confirmed by CBCT. The remaining patients were excluded from the study.

The 23 selected patients were further categorized into three groups:

Patients with monoedentulous intercalated sites (type III or IV Kennedy class).

Patients with distal edentulism of three teeth and planning for two implant fixtures (type I or II class Kennedy).

Patients with distal edentulism involving more than three missing teeth and planning for three fixtures (type I or II Kennedy class).

A total of 23 templates were thermoformed as follows: 12 templates for Group 1 (featuring a single sphere; one implant programmed), 6 templates for Group 2 (with two spheres; two implants programmed), and 5 templates for Group 3 (with three spheres; three implants programmed) (refer to Table 1).

Table 1. Samplers divided by groups.

	Group 1 (III–IV Kennedy Class)	Group 2 (I–II Kennedy Class)	Group 3 (I–II Kennedy Class)	
	Mono Edentulous Sites (One Implant)	Multiple Edentulous Sites (Two Implants)	Multiple Edentulous Sites (Three Implants)	TOTAL
Patients	12	6	5	23
Templates	12	6	5	23
Spheres	12	12	15	39

In the subsequent analysis, each individual case was independently reviewed by a second expert implantologist. This expert examined the CBCT, identified sections featuring radiopaque spheres, and then visited the patient to mark on the mucosa, using an indelible marker with a 2 mm tip, where the implant collar would be positioned.

The final phase of the study involved assessing the precision with which an expert implantologist, relying on radiographic data, could identify on the mucosa the location for positioning the implant collar.

To facilitate comparison between the presumed implant position indicated by the spheres and the points marked by the implantologist on the mucosa, each patient wore a mask.

In instances of discrepancy, the linear distance between the metal sphere and the point on the mucosa was measured to quantify the error made by the second implantologist. The analysis encompassed the correspondence between the positions of 39 metal spheres and an equal number of hypothetical implant sites, each highlighted by a marker on the mucosa.

To facilitate the grouping of results and mitigate data dispersion, all measurements were categorized and coded into three possibilities:

Zero error (indicating a precise correspondence between the metal sphere and the dot on the mucosa);

Minimal error (where the distance between the metal sphere and the dot was less than 2 mm);

Maximal error (where the distance between the metal sphere and the dot exceeded 2 mm) (see Table 2).

Table 2. Research flow chart.

Research Flow Chart			
1 >>	2 >>	3 >>	4 >>
Initial patient selection Elegibility criteria: partial edentulism	Initial identification of hypothetical implant sites (panoramic radiograph)	Drawing (permanent marker) of the implant sites on a plaster cast	Template construction
5 >>	6 >>	7 >>	8
CBCT taken with template	Definitive patient selection Elegibility criteria: fixture position confirmed by CBCT	Identification implant sites on the mucosa	Check identification accuracy by template

The reference point for scoring was set at two millimeters, aligning with the diameter of the metal spheres used in the masks, which is visible in the X-rays (refer to Table 3).

Table 3. Error score.

	Error Score		
	No Error	Minimal Error	Maximal Error
Distance between sphere in template—dot on mucosa	0 distance	<2 mm	>2 mm

3. Results

In Group 1 (monoedentulism/one implant), there was a perfect correspondence between the metal sphere incorporated in the mask and the sign on the mucosa indicated by the implantologist for eight locations. A minimal error (<2 mm) was observed for three sites, and a maximal error (>2 mm) occurred in only one case.

For Group 2 (poliedentulism/two implants), perfect correspondence between the sphere and the sign on the mucosa indicated by the implantologist for the area of the future implant was found for six locations. A minimal error (<2 mm) was present for four sites, while a maximal error (>2 mm) was recorded for two cases.

In Group 3 (poliedentulism/three implants), there was a perfect correspondence between the sphere and the sign on the mucosa for six locations. A minimal error (<2 mm) occurred for four sites, and a maximal error (>2 mm) was observed for six sites (see Table 4).

Table 4. Results divided by groups.

	Group 1 (III–IV Kennedy Class)	Group 2 (I–II Kennedy Class)	Group 3 (I–II Kennedy Class)	
	Mono Edentulous Sites (One Implant)	Multiple Edentulous Sites (Two Implants)	Multiple Edentulous Sites (Three Implants)	TOTAL
Perfect match	8	6	5	19
Distance < 2 mm	3	4	5	12
Distance > 2 mm	1	2	5	8
Total	12	12	15	39

Within each group, an assessment was conducted to determine the influence of the distance between the presumed implant site and the neighboring teeth (serving as anatomical reference points for the clinical calculation of the correct fixture position) on the choices made by the implantologist in marking the point on the mucosa. In Groups 2 and 3, the mesial implant site (closest to the remaining natural tooth) was designated as the first implant site. Subsequently, the implant site distal to the first was labeled as the second implant site.

Group 1: As these sites involve a single implant, the data presented in Table 5 are identical to those already reported in Table 4.

Table 5. Results in Group 1.

GROUP 1 (Only One Implant)			
	1° Implant Site	2° Implant Site	3° Implant Site
Perfect match	8	not applicable	not applicable
Distance < 2 mm	3	not applicable	not applicable
Distance > 2 mm	1	not applicable	not applicable
Total	12	0	0

Group 2: Concerning the first implant site, there was a perfect correspondence between the metal sphere incorporated in the mask designed for patient wear and the mark on the mucosa indicated by the implantologist as the site of the future implant in five cases. One case exhibited a minimal error (<2 mm), and there were no instances of maximal error (>2 mm). Regarding the second implant site, there was a perfect correspondence in one case between the metal sphere in the mask and the mark on the mucosa indicated by the implantologist. In three cases, there was a minimal error (<2 mm), and, in two cases, a maximal error (>2 mm) was noted (refer to Table 6).

Table 6. Results in Group 2.

GROUP 2 (Two Implants)			
	1° Implant Site	2° Implant Site	3° Implant Site
Perfect match	5	1	not applicable
Distance < 2 mm	1	3	not applicable
Distance > 2 mm	0	2	not applicable
Total	6	6	0

Group 3: For the first implant site, there was a perfect correspondence between the metal ball incorporated in the mask and the mark on the mucosa in four cases. One case exhibited a minimum error (<2 mm), and no instances of maximum error (>2 mm) were observed. Regarding the second implant site, in one case, there was perfect correspondence between the metal sphere and the mark on the mucosa indicated by the implantologist. In three cases, there was a minimum error (<2 mm), and, in one case, a maximum error (>2 mm) was noted. For the third implant site, there were no cases of perfect correspondence between the metal sphere and the mark on the mucosa indicated by the implantologist. One case exhibited a minimum error (<2 mm), and, in four cases, a maximum error (>2 mm) was observed (refer to Table 7).

Table 7. Results in Group 3.

GROUP 3 (Three Implants)			
	1° Implant Site	2° Implant Site	3° Implant Site
Perfect match	4	1	0
Distance < 2 mm	1	3	1
Distance > 2 mm	0	1	4
Total	5	5	5

4. Discussion

In today's dental practices and laboratories, the widespread use of computers and information technologies has significantly transformed the patient management information, facilitating a digital flow that speeds up clinical procedures.

The seamless transfer of clinical information from the dentist to the dental technician, in digital form, brings notable advantages for patients. A notable illustration of this digital advancement is evident in the construction of surgical guides, showcasing how a digital information flow can greatly assist implantologists, especially in intricate cases involving multiple implants [21].

In certain clinical scenarios, dentists with significant clinical experience opt for simplified protocols, bypassing the use of surgical guides for freehand implant insertion after choosing their location on CBCT.

In these cases, one of the main problems is to visually determine where the collar of the implant whose position was chosen on the CBCT will be located. Clinically, there are also other important clinical considerations such as, for example, proceeding to correctly position the implant with the angulation and depth established radiographically, but these issues are beyond the scope of this research.

The findings from this study highlight that in specific clinical conditions, such as monodentulism, identifying the precise location on the mucosa for implant placement and the subsequent implant collar proves to be straightforward [22,23]. The presence of adjacent teeth (mesial and/or distal) proximate to the edentulous site provides the surgeon with valuable reference points. However, challenges arise when the presumed implant site is distant from natural teeth, especially when only mesial or distal teeth are present (Kennedy class I or II), making the exact identification of the mucosal insertion point more challenging.

In Group 1 (a single implant between two adjacent teeth), the site on the mucosa was accurately identified without any error in 66% of cases.

In Group 2 (two implants), where the edentulous area was larger, the zero error percentage was 50% for 12 implant sites, with a distribution favoring the mesial implant sites.

For Group 3 (three implants), where the edentulous area is even larger, the percentage of correctly identified points on the mucosa dropped to 25%. Notably, in this group as well, the sites with 'zero error' pertained to the mesial implants.

Across all three groups, the proximity of the adjacent tooth proved to be instrumental in facilitating the correct identification of the point on the mucosa where the implant collar would be positioned (refer to Table 8).

Table 8. Zero error percentage.

	Group 1 (III–IV Kennedy Class) (One Implant)	Group 2 (I–II Kennedy Class) (Two Implants)	Group 3 (I–II Kennedy Class) (Three Implants)
Perfect match	66%	50%	25%

Our results indicate that in the second and third implant sites, where the distance between the selected site on the mucosa and the teeth in the arch gradually increases, the likelihood of error in clinical localization also rises.

For instance, in Group 3 (polydentulism with three implants), specifically at the third implant site, which is the furthest from the tooth in the arch, there was a precise correspondence between the metal sphere and the marked point on the mucous membrane in 0% of cases. In fact, at this level in Group 3, there was a maximum error (>2 mm) in 80% of cases.

A similar trend is observed in the data for Group 2. More precisely, the mesial implant site exhibits data similar to those of the single implant site in Group 1. On the other hand, the second implant site (the most distal) has a greater margin of error, but not as substantial as that of the third implant site in Group 3.

This imprecision, stemming from the reduced ability of the human eye to evaluate distances as the reference anatomical finding moves farther away, often prompts implantologists to use surgical templates, providing crucial indications on the axis of the fixture [24].

In clinically straightforward scenarios, such as single implant sites, surgical guides are not commonly used as the accuracy of implant placement is readily controlled.

Conversely, in complex situations like those in Group 3, with the design of three implants and the presence of critical anatomical areas like the mandibular canal, employing classic implant guides is deemed appropriate to prevent iatrogenic damages [25–27].

This preliminary study was conducted by expert implantologists, and this could serve as a limitation in the experimentation, which will be extended to clinicians with varying levels of experience to yield more comprehensive results [28,29].

In complex cases, however, the use of more expensive and intricate surgical guides appears more fitting, even for experienced implantologists [30–32]. Nonetheless, the guided system remains a more acceptable and stable option for beginners [33].

5. Conclusions

This research is a component of a broader study that scrutinizes various preliminary assessments made by implantologists during the surgical setting.

The intricate nature of the treatment, with its high biological cost for the patient, necessitates careful attention to ensure predictable results.

This study underscores that, in specific clinical scenarios, visual assessments may not be as accurate, leading to potential errors that could compromise the entire implant protocol.

In cases of monoedentulism, the freehand implant technique seems applicable with a reduced risk of error. Clinical experience aids in establishing the correct correspondence between the implant site chosen on radiographs and its identification on the mucosa [34].

The level of experience is pivotal in the clinician's decision regarding the use of surgical guides. Dentists with limited experience should consider employing surgical guides, even in simpler cases, to mitigate the risk of error [35].

While implant software significantly aids in clinical decisions, it is imperative to recognize that the responsibility for the outcome and patient safety during guided surgery ultimately rests with the surgeon. In more complex cases, especially those involving

multiple implants in large edentulous areas and situated far from landmarks like remaining natural teeth in the arch, the use of classic surgical guides appears preferable.

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