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Virtual Placement of Pterygoid Implants and Assessment of Critical Anatomical Parameters on Cone-Beam Computed Tomography in Turkish Patients with Severely Atrophic Maxillae

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Abstract

Pterygoid implants are an option for severely atrophic posterior maxillae. This study aimed to evaluate anatomical limitations, implant angulations, and bone density using pterygoid implant placement on cone-beam computed tomography (CBCT). CBCT scans of 362 atrophic posterior maxillae in patients aged > 50 years were retrospectively analyzed between April 2023 and March 2025. Virtual implants (4 mm in diameter; 13–20 mm in length) were placed bicortically with a minimum 2 mm safety margin from the greater palatine canal (GPC), avoiding sinus perforation. Mesio-distal (M-D) and bucco-palatal (B-P) angulations, shortest GPC distance, and bone density were recorded for successful placements. Placement was successful in 147 of 362 regions (40.6%). Implant lengths were 13 mm (61.9%), 15 mm (29.3%), and 18 mm (8.8%). Mean M-D and B-P angulations were 64.62° ± 7.78° and 63.79° ± 8.17°, respectively, and minimum GPC distance was 2.85 ± 0.93 mm. Inadequate GPC clearance was the primary cause of failure. Although implant angulations were consistent with previous reports, placement success rate was lower than reported previously. This lower success rate is considered related to advanced maxillary atrophy of patients. These findings highlight the importance of population-specific anatomy and strict GPC safety margins for predictable pterygoid implant planning.

INTRODUCTION

Since the introduction of the osseointegration concept by Brånemark, dental implants have become the gold standard for treating edentulism [1]. The primary goal in these applications is to place implants, preferably during the same session with prostheses, and to rehabilitate patients functionally and esthetically in the shortest possible time [2]. However, significant bone resorption and volume deficiencies resulting from long-term tooth loss, combined with the limitations of surrounding anatomical structures, render implant surgery a complex process with a high risk of complications [3].

In patients with advanced resorption in the maxillary posterior region, various bone augmentation methods such as iliac crest-derived block grafts, onlay grafting techniques, or maxillary sinus lift operations can be preferred [4]. In addition, as an alternative to traditional implant applications and extensive grafting procedures in cases of advanced resorption, implant techniques developed by gaining support from areas such as the zygomatic bone and pterygoid process have been introduced.

Pterygoid implants, first described by Tulasne in 1989, provide a triple cortical support by advancing through the maxillary tuber, the pyramidal process of the palatine bone, and the pterygoid process of the sphenoid bone. The bone density of these supported regions (Type I/II) differs from the low bone density (Type III/IV) normally found in the posterior maxilla. In this way, pterygoid implant application eliminates the need for grafting and enables immediate occlusal restoration in a severely atrophic maxilla [5].

Despite all these advantages, pterygoid implant application presents serious clinical challenges that require the surgeon to have comprehensive and deep knowledge of the regional anatomy [6]. Maintaining a safe surgical distance from the greater palatine canal (GPC), which houses the descending palatine artery one of the terminal branches of the maxillary artery and its accompanying neurovascular

bundle, is extremely important [7]. Although there are studies to assist in the ideal three-dimensional positioning of pterygoid implants, there is still no consensus in the literature regarding the ideal angulation. While some researchers have suggested placing the implant at a 45° inclination relative to the Frankfort horizontal plane, other studies have stated that implants applied at a 70° inclination withstand non-axial forces better and show a longer survival rate [8].

A remarkable point is that previous research has been largely limited to individuals of white European descent (Caucasian). It is an accepted fact that there are distinct anatomical differences between individuals of different ethnic origins; for example, variations such as high third molar agenesis and narrower maxillary tuberosity dimensions observed in Asian populations have been reported in the literature. However, a detailed analysis of these anatomical limits and pterygoid implant placement success in atrophic cases within the Turkish population has not yet been sufficiently included in the literature [9], [10].

The purpose of this study was to determine critical anatomical limitations by virtually placing pterygoid implants on cone-beam computed tomography (CBCT) and to establish guidelines that will assist the clinician in an ideal pterygoid implant placement.

MATERIALS AND METHODS

Ethical Approval and Study Design

This retrospective study was conducted as a collaborative investigation between the Departments of Oral and Maxillofacial Surgery and Oral and Maxillofacial Radiology at Recep Tayyip Erdoğan University, Faculty of Dentistry. Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Recep Tayyip Erdoğan University (Approval No: 2025/34; 23 January 2025). Cone-beam computed tomography (CBCT) data evaluated in this study were retrieved from the radiographic archives of patients who attended the Faculty of Dentistry between April 2023 and March 2025. Written informed consent was obtained from all participants prior to CBCT imaging.

Patient Selection Criteria

The inclusion criteria for the study were as follows: patients aged 50 years or older, complete molar edentulism in the maxilla (absence of the maxillary first, second, and third molars), a vertical residual ridge height of 4 mm or less measured from the alveolar crest to the lowest point of the maxillary sinus floor in the molar region, and a horizontal distance of 6 mm or less between the distal wall of the maxillary sinus and the anatomical end of the tuberosity. Conversely, patients under 50 years of age, cases with teeth present in the designated regions, individuals with congenital defects or syndromes, and patients presenting with major surgical jaw defects such as maxillectomy were excluded from the study.

Virtual Implant Placement and Success Criteria

Pterygoid implants utilized in the virtual simulations were selected from the software library of the CBCT system (NewTom, Verona, Italy) and positioned three-dimensionally. All virtual implants shared a standard diameter of 4 mm, with available lengths varying among 13, 15, 18, and 20 mm. In each region, clinicians attempted to place the longest possible virtual pterygoid implant allowed by the bone anatomy; if an implant failed to satisfy the anatomical parameters, the next shorter implant size was selected, and the measurements were repeated. Based on established literature, a virtual pterygoid implant placement was defined as successful if it fulfilled the following criteria: the entry point of the virtual pterygoid implant should ideally be within the second molar region (although deviations toward the third molar area were permitted to avoid critical anatomical structures), the implant must be completely free of contact with or perforation into the maxillary sinus, the implant must achieve bicortical engagement by anchoring within cortical bone layers in both the coronal and apical portions, the implant must be surrounded by a minimum of 1 mm of intact bone thickness circumferentially, and a safe surgical distance of at least 2 mm must be maintained from the greater palatine canal (GPC).

CBCT Standardization and Measurements

All radiographic images were acquired using a NewTom VGi Evo CBCT unit (NewTom, Verona, Italy) operating at parameters of 75–110 kVp and 1–32 mA. Archive scans deemed diagnostically sufficient for other clinical indications were included if the bilateral pterygoid regions were fully captured within the field of view (FOV ≥ 12 x 15 cm) with a voxel size ranging between 0.2 and 0.3 mm. To ensure standardized measurements, the orientation of each scan was adjusted so that the horizontal reference plane was perfectly parallel to the Frankfort Horizontal plane, while the patient's midsagittal plane was oriented perpendicular to the floor.Following the successful placement of the longest eligible virtual implant, the following variables were recorded: the mesio-distal (M-D) angulation relative to the Frankfort Horizontal plane was measured on the central axis of the implant in the sagittal slice, while the bucco-palatal (B-P) angulation was measured in the coronal slice (Fig. 1, Fig. 2). The shortest distance between the implant surface and the greater palatine canal (GPC) was measured on the axial slice (Fig. 3). Bone density at the implant site was recorded in Hounsfield Units (HU) using the proprietary NewTom (NNT) software module.

Statistical Analysis

The minimum required sample size was calculated using G*Power software (v3.1.9.7). For a one-sample t-test design, assuming a power of 0.95, an effect size of 0.3, and a significance level (alpha) of 0.05, a minimum of 147 successfully placed implants was determined to be necessary. Statistical analyses were performed using IBM SPSS Statistics v26 software. Normal distribution of the data was verified by ensuring that the skewness and kurtosis coefficients remained within the range of ± 1.5. Intergroup

comparisons were analyzed using Independent Samples T-tests, One-Way ANOVA, and Chi-Square tests. The level of statistical significance was set at $p < 0.05$.

RESULTS

Within the scope of the study, cone-beam computed tomography (CBCT) images of a total of 362 maxillary posterior half-jaws (right and left regions were evaluated separately) belonging to patients aged 50 years and older were examined. While virtual pterygoid implants could be successfully placed in 40.6% (n = 147) of these evaluated regions in accordance with the specified criteria, the placement criteria could not be met in 59.4% (n = 215) of them.

Of the examined regions, 44.5% belonged to female patients (n = 161) and 55.5% belonged to male patients (n = 201). A statistically significant relationship was found between gender and implant placement success ($p < 0.05$). The implant placement success rate was 32.9% in female patients, whereas it was determined as 46.7% in male patients. Anatomical suitability for pterygoid implant placement in the atrophic posterior maxilla was observed to be significantly higher in male patients compared to females. Of the 147 virtual pterygoid implants successfully placed, 36.1 (n = 53) % belonged to female patients, while 63.9 (n = 94) % belonged to male patients. In terms of mean age, no statistically significant difference was found between the successful (61.64 ± 7.03) and unsuccessful (63.03 ± 7.33) groups ($p > 0.05$) (Table 1).

Table 1
Demographic findings of the study groups

Gender	**Successful (n = 147)**		**Unsuccessful (n = 215)**		**Chi-Square (χ2)**	**p**
	Count (n)	**Percentage (%)**	**Count (n)**	**Percentage (%)**		
					7,107	**0.008***
Female	53	36.1	108	50.2		
Male	94	63.9	107	49.8		
	Mean ± SD	**Min-Max**	**Mean ± SD**	**Min-Max**	**t**	**p**
Age	61.64 ± 7.03	51–78	63.03 ± 7.33	50–80	-1.798	0.073

Note: Data are presented as count (percentage) or mean ± standard deviation (SD). [a] Pearson's chi-square test. [b] Independent samples t-test. *Statistically significant at $p < 0.05$.

When the length distributions of the 147 virtual pterygoid implants placed in accordance with the criteria were examined, it was observed that 91 implants (61.9%) were 13 mm, 43 implants (29.3%) were 15 mm, and 13 implants (8.8%) were 18 mm in length. Implant placement with a length of 20 mm could not be performed in any case in accordance with the criteria. The mean mesio-distal (M-D) angulation of the

placed implants in the sagittal slice relative to the Frankfort Horizontal plane was measured as 64.62°, while the mean bucco-palatal (B-P) angulation in the coronal slice was measured as 63.79°. The mean shortest distance between the implants and the Greater Palatine Canal (GPC) was determined as 2.85 ± 0.93 mm, and the mean bone density in the area where the virtual pterygoid implants were placed was found to be 319.49 ± 122.27 HU. In comparisons made between the right and left sides, no statistically significant difference was observed in any of the measured parameters ($p > 0.05$) (Table 2).

Table 2
Implant characteristics and measurements in the successful group (n = 147)

Implant Diameter	**n**	**%**
4 mm	147	100.0
Implant Length		
13 mm	91	61.9
15 mm	43	29.3
18 mm	13	8.8
Side		
Right	69	46.9
Left	78	53.1
	Mean ± SD	**Min-Max**
M-D Angle	64.62 ± 7.78	45-84.1
B-P Angle	63.79 ± 8.17	45-89.6
GPC Distance (mm)	2.85 ± 0.93	2-5.8
Bone density at the implant site (Mean)	319.49 ± 122.27	95.2–633
Bone density at the implant site (Standard Deviation)	156.41 ± 58.59	51.2–311
Note: Data are presented as count (percentage) or mean ± standard deviation (SD).		

When the 215 implants that could not be placed in accordance with the criteria were evaluated, it was determined that the most common cause of failure was insufficient distance to the GPC with a rate of 61.9% (n = 133). The lack of adequate bone support around the implant (being less than 1 mm) led to implant failure in 36.3% (n = 78) of the cases, while the risk of maxillary sinus perforation was determined as the cause of failure in 1.9% (n = 4) of the cases (Table 3). Here, it should be noted that the primary priority when placing virtual pterygoid implants was not to cause perforation in the maxillary

sinus and to ensure at least 1 mm of intact bone thickness around the implant. Implants were positioned in line with these criteria, and subsequently, the distance to the GPC was recorded.

Table 3
Implant characteristics and findings in the unsuccessful group (n = 215)

Side	**n**	**%**
Right	107	49.8
Left	108	50.2
Condition		
Insufficient bone around the implant	78	36.3
Insufficient distance to the GPC	133	61.9
Maxillary sinus perforation	4	1.9
Note: Data are presented as count (percentage)		

DISCUSSION

Progressive resorption and sinus pneumatization observed in the maxillary bone, along with advancing age and the increase in tooth loss, severely complicate the application of conventional dental implants, particularly in the posterior region [11]. Placing a dental implant into an atrophic posterior maxilla can be highly challenging due to the complex anatomical structure of the region, the presence of the maxillary sinus, low bone volume and quality, and limited surgical Access [12]. Although advanced surgical augmentation techniques offer an alternative solution in the rehabilitation of this region, disadvantages such as prolonged treatment time, increased costs, and donor site morbidity have led clinicians toward anatomical anchorage methods, such as pterygoid implants, which eliminate the need for grafting [13]. In the literature, it is reported that pterygoid implants provide high primary stability, allowing for immediate loading, and exhibit high long-term success rates [14]. Concurrently, because pterygoid implants are applied from the second or third molar region, the use of long distal cantilevers is not required during the prosthetic rehabilitation phase. However, the highly complex anatomical structure of the pterygomaxillary region, the difficulty of accessing the relevant area, and the risk of hemorrhage render pterygoid implant surgery precise and demanding of high experience [15]. In our study, the distribution of these anatomical boundaries and the success of virtual implant placement in Turkish patients with atrophic maxillae were analyzed in detail using cone-beam computed tomography (CBCT).

In most studies, it is reported that the implants to be applied must be between 13.0 and 18.0 mm in length to gain support from the pterygoid process [16]. In studies conducted by Rodríguez et al. and Balshi et al., it was stated that choosing pterygoid implants with a diameter between 3.75 mm and 4.00

mm and a length between 15 mm and 18 mm would ensure good clinical success, and that the anatomy of most patients is suitable for this [12], [14], [16]. Accordingly, the minimum implant length was determined as 13 mm and the diameter as 4 mm in our study. While virtual implant placement was successfully performed in 40.6% of the 362 regions examined, the most preferred length was 13 mm with a rate of 61.9%; in no case could a 20 mm length implant placement be performed in accordance with the criteria. As a result of the study conducted by Uchida et al. on 46 Japanese cadavers, it was stated that applying a pterygoid implant longer than 15 mm to a patient of North Mongolian race (including Japanese) with an atrophic maxilla could lead to significant complications due to insufficient bone in the region [8]. Our findings exhibit parallelism with this information. Although Rodriguez et al. indicated that longer implants could be used, the fact that their study was conducted on Caucasian (white race) patients highlights the morphological variations between populations[12], [16].

In contrast, in the study by Zhang et al., which reported a virtual implant placement success rate of 67% in the Chinese population, the most frequently preferred implant length was reported as 15 mm (77.6%). It is considered that this distinct success rate and implant length difference in the literature between our study and that of Zhang et al. stems from the inclusion of young individuals over 18 years old in their study, whereas our study targeted a homogeneous age group entirely over 50 years old with advanced atrophic ridges[10]. Progressive resorption seen in bone volume with advancing age directly limits the applicable implant length.

In conducted studies, certain areas in the pterygomaxillary region have been examined in terms of the gender factor, and significantly higher results were obtained in male individuals compared to females [17], [18]. Of the 362 maxillary posterior regions examined in our study, 161 belonged to female and 201 belonged to male patients; virtual placement was successful in 32.9% of female patients, while success was achieved in 46.7% of male patients. This finding serves as a critical clinical warning for surgeons; it must always be kept in mind that the anatomical corridor can be markedly narrower when planning pterygoid implants in female patients. On the other hand, the absence of a significant difference in mean age between the successful and unsuccessful groups demonstrates that age-related bone losses observed after the fifth decade of life affect the macroscopic surgical boundaries in the pterygoid region similarly, independent of chronological age.

Angulations made according to the Frankfort Horizontal (FH) plane are one of the most important discussion topics in the three-dimensional ideal positioning of pterygoid implants [12]. While some authors find it appropriate to place them at an average angle of 45° relative to the FH plane, others state that placement at an angle of 70° is healthier [12], [13], [19]. The objective of researchers, particularly working on these angulations, is to ensure that the implant can reach the pterygoid region and counter forces in the best possible way by mimicking the angulation of the molars [20]. Generally speaking, while a 45-degree angle was proposed in the initial studies on pterygoid implants, opinions that a 70-degree angulation would be healthier have gained weight in studies conducted up to the present day. It has been stated that applying a pterygoid implant with a 45-degree mesio-distal (M-D) angulation reduces its load-bearing capacity by 50% compared to a 90-degree angulation. The angulation of maxillary second

molars in the same axis is accepted as approximately 75 degrees relative to the FH plane. Therefore, it is thought that an average angle of 70 degrees can minimize horizontal forces transmitted to the pterygoid implant [21].

In our study, the mean value of the M-D angulation of virtually placed pterygoid implants relative to the FH plane in the sagittal axis was found to be 64.62° with a standard deviation of 7.78°. Additionally, the mean value of the bucco-palatal (B-P) angulation relative to the FH plane in the coronal axis was measured as 63.79° with a standard deviation of 8.17°. As a result of their studies on CBCT, Rodriguez et al. specified the mean M-D angulation as 72.5 ± 24.9° and the mean B-P angulation as 81.3 ± 2.8° [16]. Zhang et al. placed virtual pterygoid implants on CBCT and, as a result of this study covering Chinese patients, reported that the mean M-D angulation was 45.08 ± 2.56° and the mean B-P angulation was 64.30 ± 4.99° [10].

In their study, Uchida et al. performed measurements by determining two different points on the maxillary alveolar ridge. One of these points is the lowest and posterior point of the maxillary tuberosity, while the other is located more anteriorly (between the first and second molars). Consequently, the M-D angle of the implant applied from the anterior will be smaller (narrower), whereas the implant applied from the posterior will have a more vertical angle. As a result of the study, the measurement taken from the tuberosity was reported as an average of 75.1°, and the measurement taken more anteriorly at the level of the molars was reported as an average of 52.3° [8], [12]. The M-D angulation values we obtained show a similar trend to the tuberosity-centered measurements of Rodriguez et al. and Uchida et al. However, it is markedly higher than the data of Zhang et al., who reported the M-D angle as 45.08° in the Chinese population. Our B-P angulation value appears compatible with the results of Zhang et al[10], [12], [16].

In their study conducted on 60 Vietnamese patients, Luong et al. identified five points on the ridge with a distance of 2 mm between them on CBCT, and evaluated their angulations by applying virtual pterygoid implants from these points. As a result of the study, it was stated that the probability of placing a pterygoid implant without causing maxillary sinus perforation significantly decreased from posterior (85.8%) to anterior (43.3%). Furthermore, it was reported that as the entry point of the implant progressed from posterior to anterior, the required implant lengths increased and the implant angulations decreased (narrowed)[22]. As a result of the study they conducted, the values measured in the posterior were found to be compatible with the studies of Rodriguez et al., while the angulation values in the anterior were found to be compatible with the study conducted by Zhang et al. At this point, it is clearly seen that the entry site of the implant significantly affects the implant length and angulation[10], [16], [22].

In our study as well, a specific entry point was not fixed; virtual pterygoid implants were placed by selecting the longest length implant that would not cause sinus perforation and would maintain a distance of at least 2 mm from the Greater Palatine Canal (GPC). In addition, the application was performed from the level of the second molar as much as possible. After the virtual pterygoid implants

were placed, the distance between the implant and the GPC was measured relative to the FH plane in the axial slice. The distance between the implants and the GPC was determined as an average of 2.85 ± 0.93 mm. In their study, Zhang et al. measured the distance between the GPC and the apex of the virtual pterygoid implants in the coronal axis and stated that it was 3.91 ± 0.62 mm [10]. It is evaluated that this difference arises from the fact that in our study, the measurement was taken in the axial slice from any point where the implant body was closest to the canal as the shortest three-dimensional distance. This finding reveals that the surgeon must perform meticulous three-dimensional planning to avoid descending palatine artery injuries in atrophic cases within the Turkish population.

Bone density measurement in Hounsfield Units (HU) on CBCT devices is still controversial in the literature due to inter-device calibration differences and gray scale value (GSV) standardization issues [23]. Nevertheless, there are studies reporting a high correlation between CBCT and CT density measurements and showing that results very close to the HU value can be obtained with calibrated software [24], [25]. In our study, virtual pterygoid implants were placed in the most appropriate position, and subsequently, the density of the bone in the area where the implant was placed was measured in HU. The bone density in the area where the implants were placed was determined as an average of 319.49 ± 122.27 HU. Lins et al. evaluated the densities of 40 maxillary tuber and pterygoid regions on CBCT and shared the results in HU. While the mean density value in the tuber region was 216.4 HU, the bone density of the pterygoid region was stated as 632.3 HU [26]. Zhang et al., on the other hand, reported the maxillary tuber region as an average of 412.06 ± 153.34 HU and the pterygoid region as 668.67 ± 124.10 HU [10]. In their study conducted on 202 CBCTs, Rodriguez et al. measured the bone densities of the tuberosity and pterygoid regions and shared the results in Density Value (DV). The mean bone density in the tuberosity region was measured as 307.4 ± 155.94 DV, while the mean bone density in the pterygoid region was measured as 632 ± 209.73 DV [12]. Since the bone density values obtained in the present study reflect the anatomical site of implant placement, they are expected to fall within the range of values reported in the literature for the maxillary tuberosity and the pterygoid region. Accordingly, while our findings appear to be consistent with those of Lins et al. and Rodríguez et al., lower bone density values were observed in our study compared to those reported by Zhang et al. [10], [12], [26]. It is thought that these differences stem from the ages and edentulous statuses of the patients included in the study. Furthermore, it should not be forgotten that the CBCT devices used in the studies belong to different brands, and therefore a completely accurate comparison is not possible.

Additionally, it is known that oral and dental health awareness is low in the Turkish population, and patients lose their teeth at an early age, remaining edentulous for long periods [27]. As a result of this, it is clearly seen through our study that bone density and quantity regress to very low amounts over time, making it difficult to find sufficient bone even for placing a pterygoid implant. In the study, 362 maxillary and pterygoid regions were examined, and a pterygoid implant could not be applied to 215 regions. The biggest reason for this situation is the lack of sufficiently sound bone around the implant, and that a pterygoid implant placed without causing perforation in the maxillary sinus would highly likely cause perforation in the GPC.

The limitation of this study is that the evaluations were made entirely in a computer environment with virtual simulations and do not include clinical/dynamic surgical loading results. Nonetheless, the data obtained present a standard and strong guideline regarding the posterior maxillary anatomical boundaries of the Turkish population.

CONCLUSION

In conclusion, although pterygoid implants in the atrophic posterior maxilla offer a strong and reliable alternative that eliminates the need for complex and risky bone grafting procedures, the risk of Greater Palatine Canal (GPC) perforation is highly elevated. This surgical risk increases significantly in female patients, where the anatomical corridor is severely narrowed, in advanced age groups, and in highly resorbed ridges. Therefore, to prevent dangerous vascular complications such as descending palatine artery injury and to achieve a successful bicortical anchorage, it is mandatory to perform a meticulous patient-specific three-dimensional evaluation and planning with CBCT prior to the operation.

Declarations

AUTHOR CONTRİBUTİONS

E.B.: Conceptualization, literature review, supervision, and writing—review and editing.

D.S.D.: Literature review, methodology, virtual implant placement, CBCT measurements, data curation, formal analysis, writing—original draft, and writing—review and editing.

T.E.K.: Radiological methodology, supervision of CBCT measurements, interpretation of radiological findings, and writing—review and editing.

M.K.: Language editing and writing—review and editing.

Y.B.A.: Literature review and writing—review and editing.

All authors critically reviewed the manuscript, approved the final version, and agreed to its submission.

DATA AVAİLABİLİTY

The datasets generated and/or analyzed during the current study are not publicly available due to ethical and privacy restrictions but are available from the corresponding author on reasonable request.

ADDİTİONAL INFORMATİON

The authors declare that they have no competing financial or non-financial interests. This study was derived from the specialization thesis of Dr. Dilara Sevinç Doğan.

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ETHİCS APPROVAL

This study was approved by the Non-Interventional Clinical Research Ethics Committee of Recep Tayyip Erdoğan University (Approval No: 2025/34; 23 January 2025) and was conducted in accordance with the principles of the Declaration of Helsinki.

References

1. Brånemark, P. I. et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period, *Scand. J. Plast. Reconstr. Surg. Suppl.*, vol. 16, pp. 1–132, 1977, Accessed: Jun. 23, 2026. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/356184/
2. van Steenberghe, D. et al. A custom template and definitive prosthesis allowing immediate implant loading in the maxilla: a clinical report, *Int. J. Oral Maxillofac. Implants*, vol. 17, no. 5, pp. 663–70, Accessed: Jun. 23, 2026. [Online]. (2002). Available: https://pubmed.ncbi.nlm.nih.gov/12381066/
3. Agliardi, E., Panigatti, S., Clericò, M., Villa, C. & Malò, P. Immediate rehabilitation of the edentulous jaws with full fixed prostheses supported by four implants: interim results of a single cohort prospective study. *Clin. Oral Implants Res.* **21** (5), 459–465. 10.1111/J.1600-0501.2009.01852.X (May 2010).
4. Candel-Martí, E., Carrillo-García, C., Peñarrocha-Oltra, D. & Peñarrocha-Diago, M. Rehabilitation of atrophic posterior maxilla with zygomatic implants: review. *J. Oral Implantol*. **38** (5), 653–657. 10.1563/AAID-JOI-D-10-00126 (Oct. 2012).
5. Tulasne, J. F. Implant treatment of missing posterior dentition. In: Albrektsson T, Zarb GA (eds) The Brånemark Osseointegrated Implant., *Quintessence, Chicago*, pp. 103–115, (1989).
6. Broumand, V. & Kirchhofer, J. Pterygoid implants as alternative to bone augmentation in implant dentistry. *Br. Dent. J.* **238** (2), 99–109. 10.1038/S41415-024-8274-Y (Jan. 2025).
7. Balaji, V., Lambodharan, R., Manikandan, D. & Deenadayalan, S. Pterygoid Implant for Atrophic Posterior Maxilla. *J. Pharm. Bioallied Sci.* **9**, S261–S263. 10.4103/JPBS.JPBS_103_17 (Nov. 2017).
8. Uchida, Y., Yamashita, Y., Danjo, A., Shibata, K. & Kuraoka, A. Computed tomography and anatomical measurements of critical sites for endosseous implants in the pterygomaxillary region: a cadaveric study, *Int. J. Oral Maxillofac. Surg.*, vol. 46, no. 6, pp. 798–804, Jun. (2017). 10.1016/j.ijom.2017.02.003
9. Sánchez, M. J., Vicente, A. & Bravo, L. A. Third molar agenesis and craniofacial morphology. *Angle Orthod.* **79** (3), 473–478. 10.2319/052008-276.1 (May 2009).
10. Zhang, Q., Abdelrehem, A., Qu, X. Z., Zhang, C. P. & Ong, H. S. Radiographic analysis of critical anatomical structures for pterygoid implant placement in Chinese patients with a severely atrophied

maxilla, *Int. J. Oral Maxillofac. Surg.*, vol. 52, no. 9, pp. 998–1004, Sep. (2023). 10.1016/j.ijom.2023.01.005

11. Lombardo, G. et al. Clinical, microbiologic and radiologic assessment of soft and hard tissues surrounding zygomatic implants: a retrospective study. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol.* **122** (5), 537–546. 10.1016/j.oooo.2016.06.011 (Nov. 2016).
12. Rodríguez, X. et al. Anatomical and radiological approach to pterygoid implants: a cross-sectional study of 202 cone beam computed tomography examinations. *Int. J. Oral Maxillofac. Surg.* **45** (5), 636–640. 10.1016/J.IJOM.2015.12.009 (May 2016).
13. Curi, M. M., Cardoso, C. L. & de Ribeiro, K. Retrospective study of pterygoid implants in the atrophic posterior maxilla: implant and prosthesis survival rates up to 3 years, *Int. J. Oral Maxillofac. Implants*, vol. 30, no. 2, pp. 378–383, Mar. (2015). 10.11607/JOMI.3665
14. Balshi, T. J., Wolfinger, G. J., Slauch, R. W. & Balshi, S. F. Brånemark system implant lengths in the pterygomaxillary region: a retrospective comparison. *Implant Dent.* **22**, 610–612. 10.1097/ID.0B013E3182A5D181 (Dec. 2013).
15. Motiwala, I. A. & Bathina, T. A Radiographic Study on Pterygoid Implants with Hamulus as a Landmark for Engaging the Pterygoid Plate - A Retrospective Study, *Ann. Maxillofac. Surg.*, vol. 12, no. 2, pp. 190–196, Jul. (2022). 10.4103/AMS.AMS_132_22
16. Rodriguez, X. et al. Anatomical study of the pterygomaxillary area for implant placement: cone beam computed tomographic scanning in 100 patients, *Int. J. Oral Maxillofac. Implants*, vol. 29, no. 5, pp. 1049–1052, Sep. (2014). 10.11607/JOMI.3173
17. Ueki, K. et al. Determining the anatomy of the descending palatine artery and pterygoid plates with computed tomography in Class III patients. *J. Craniomaxillofac. Surg.* **37** (8), 469–473. 10.1016/J.JCMS.2009.03.010 (Dec. 2009).
18. Se, H. H. et al. An anatomic study using three-dimensional reconstruction for pterygopalatine fossa infiltration via the greater palatine canal, *Clin. Anat.*, vol. 24, no. 5, pp. 576–582, Jul. (2011). 10.1002/CA.21134
19. Bidra, A. S. & Huynh-Ba, G. Implants in the pterygoid region: A systematic review of the literature, *Int. J. Oral Maxillofac. Surg.*, vol. 40, no. 8, pp. 773–781, Aug. (2011). 10.1016/j.ijom.2011.04.007
20. Oral Anatomy. Histology and Embryology – 6th Edition | Elsevier Shop. Accessed: Jun. 24, 2026. [Online]. Available: https://shop.elsevier.com/books/oral-anatomy-histology-and-embryology/berkovitz/978-0-323-93521-0
21. Rodriguez, X. & Méndez, V. Modified Surgical Protocol for Placing Implants in the Pterygomaxillary Region: Clinical and Radiologic Study of 454 Implants, [Online]. (2012). Available: https://www.researchgate.net/publication/233790007
22. Luong, D. C., Lanh, L. D., Thuy, V. L. & Loan, P. T. H. Optimizing pterygoid implant placement without sinus intrusion in edentulous vietnamese patients: A comprehensive tomographic analysis and cross-sectional study. *J. Clin. Exp. Dent.* **16** (11), e1371–e1378. 10.4317/JCED.61787 (2024).

23. Emadi, N., Safı, Y., Bagheban, A. A. & Asgary, S. Comparison of CT-Number and Gray Scale Value of Different Dental Materials and Hard Tissues in CT and CBCT, (2014).
24. Mah, P., Reeves, T. E. & McDavid, W. D. Deriving Hounsfield units using grey levels in cone beam computed tomography, *Dentomaxillofac. Radiol.*, vol. 39, no. 6, pp. 323–335, Sep. (2010). 10.1259/DMFR/19603304
25. Naitoh, M., Hirukawa, A., Katsumata, A. & Ariji, E. Evaluation of voxel values in mandibular cancellous bone: relationship between cone-beam computed tomography and multislice helical computed tomography. *Clin. Oral Implants Res.* **20** (5), 503–506. 10.1111/J.1600-0501.2008.01672.X (May 2009).
26. Lins, R. N. F., Silva, M. L. M., de Oliveira-Neto, O. B., de Macêdo, L. F. C. & Sales, P. H. Tomographic Analysis of the Pterygomaxillary Region in Atrophic Maxilla for the Placement of Pterygoid Implants, *J. Maxillofac. Oral Surg.*, vol. 24, no. 4, pp. 1029–1034, Aug. (2025). 10.1007/S12663-024-02338-7
27. Gökalp, S. G., Guciz Doğan, B., Tek Tekçiçek, M. & Berberoğlu, A. Unlüer National survey of oral health status of children and adults in Turkey. *Community Dent. Health*. **27** (1), 12–17 (2010). PMID: 20426255.

Figures

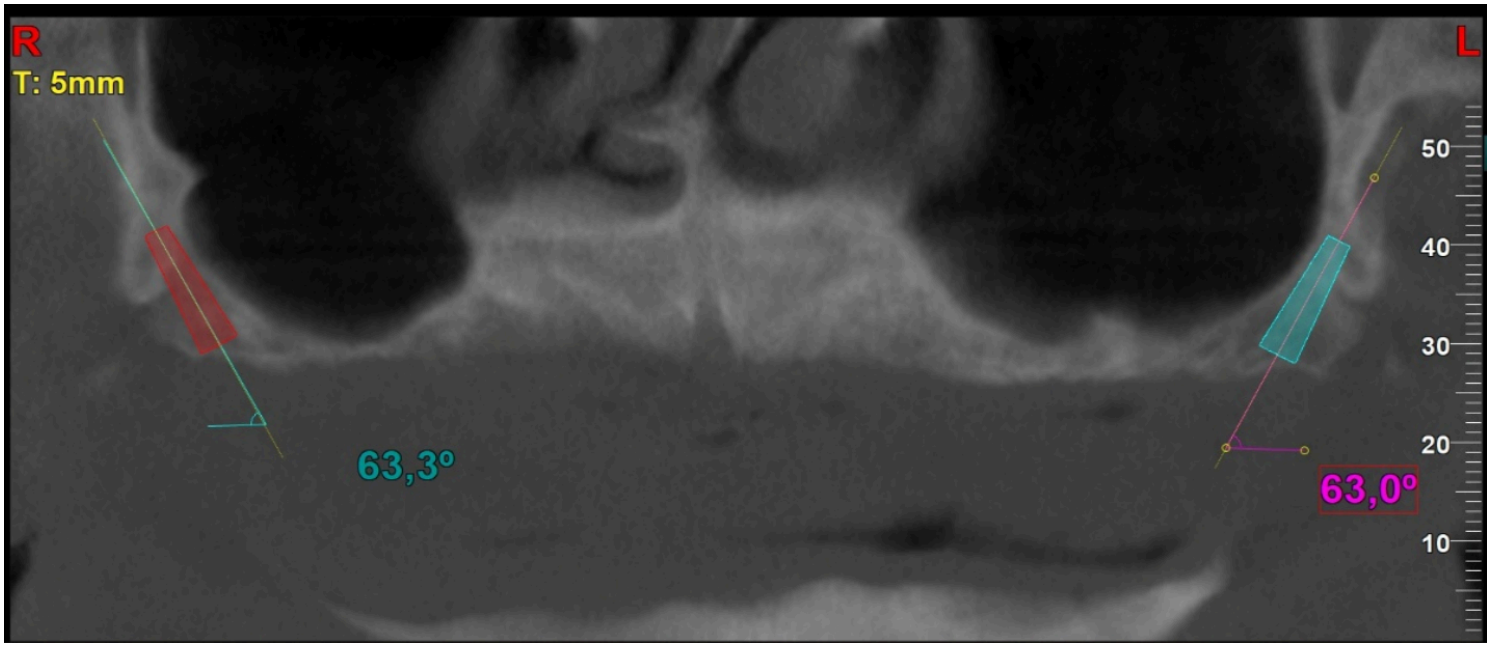


Figure 1

Mesiodistal (M–D) angulation relative to the Frankfort Horizontal (FH) plane on the sagittal view passing through the implant's central axis

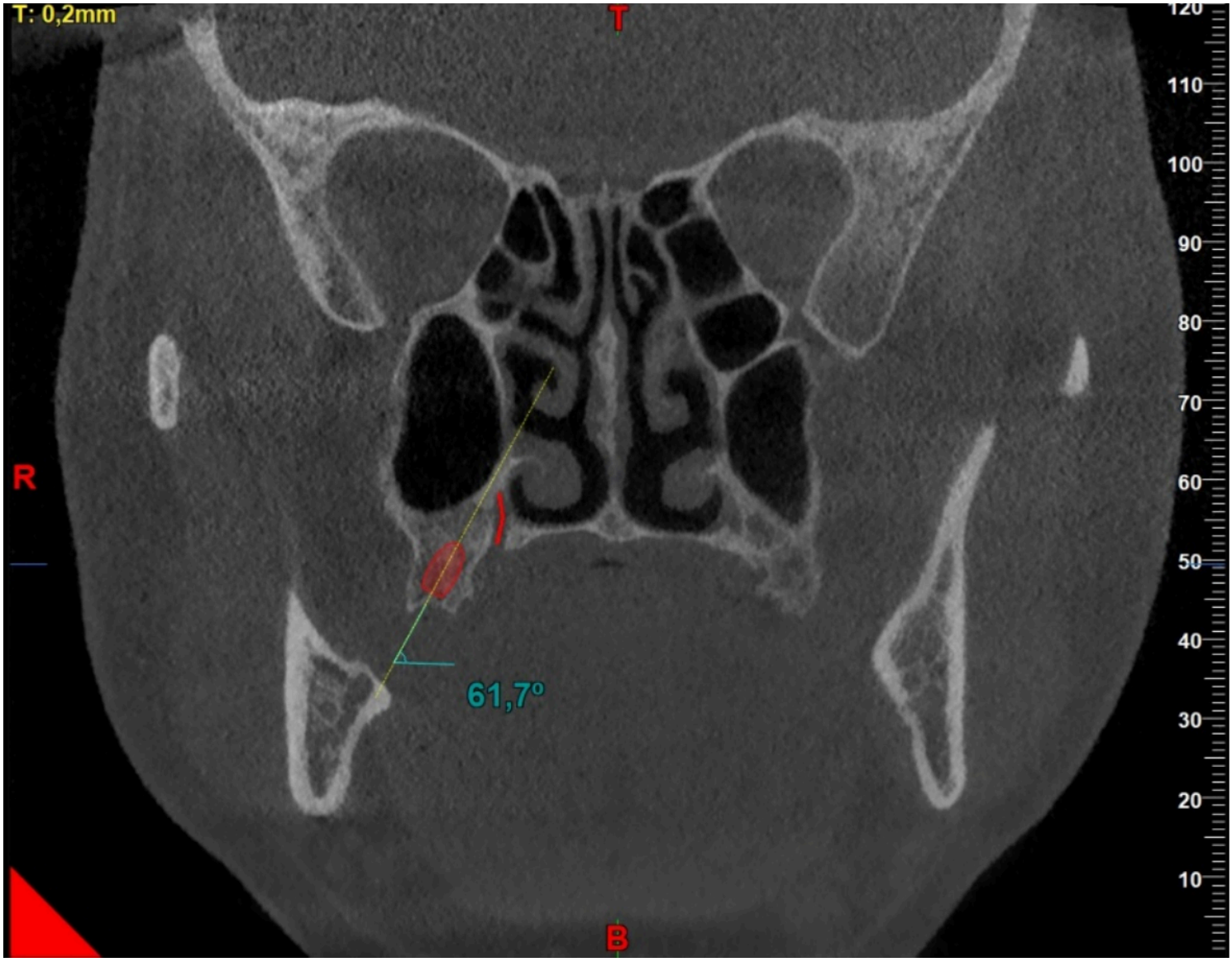


Figure 2

Buccopalatal (B–P) angulation relative to the Frankfort Horizontal (FH) plane on the coronal view passing through the implant's central axis (the red line indicates the greater palatine canal [GPC])

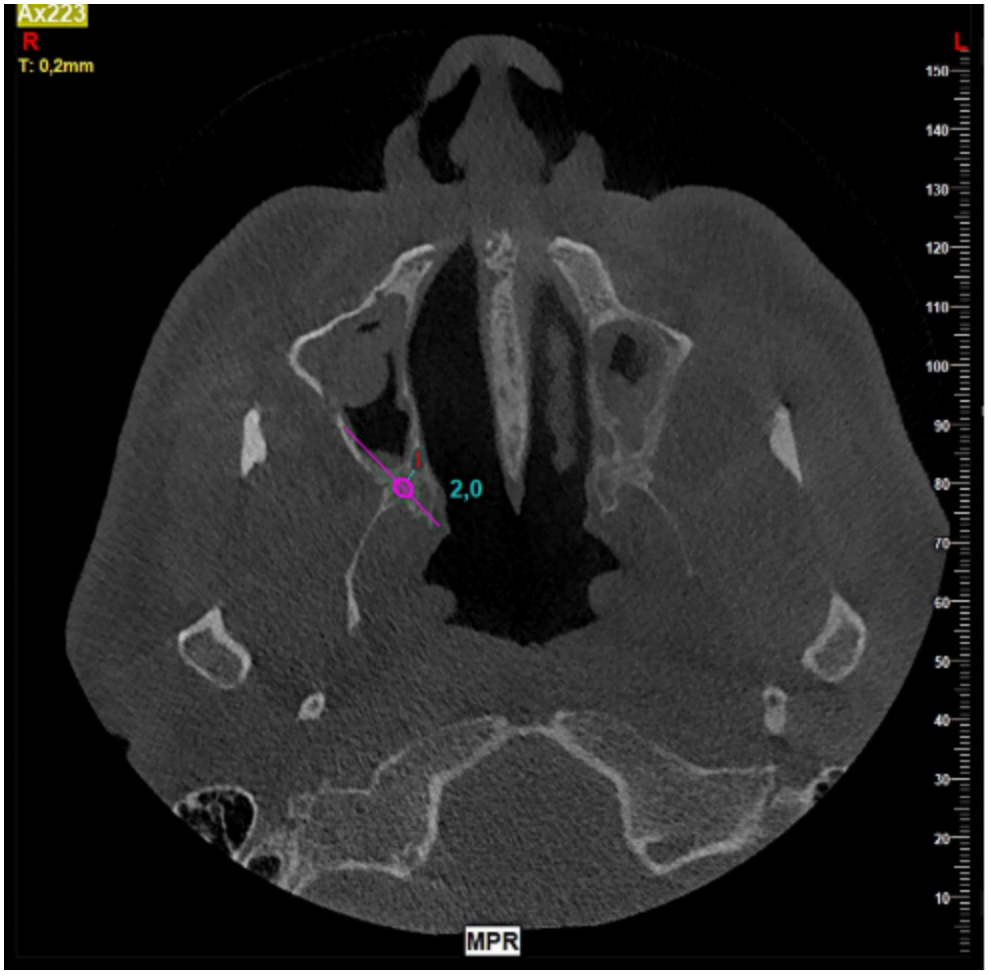


Figure 3

Shortest distance between the implant and the greater palatine canal (GPC) on the axial view passing through the implant's central axis (the red line indicates the greater palatine canal [GPC]).