Original Article - Retrospective Study

A Radiographic Study on Pterygoid Implants with Hamulus as a Landmark for Engaging the Pterygoid Plate - A Retrospective Study

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Abstract

Introduction: Rehabilitating the posterior maxilla with pterygoid implants can be quite challenging as the area entails many hindrances for implant placement. Although few studies have reported the three-dimensional angulations according to various planes (Frankfort horizontal (FH), sagittal plane, occlusal or maxillary planes), no anatomical landmarks have been identified to guide their placement. This study aimed at analysing the three-dimensional angulation of pterygoid implants using the hamulus as an intraoral guide. **Methods:** Pre-operative cone-beam computed tomography scans (axial and parasagittal sections) of 150 patients rehabilitated with pterygoid implants were retrospectively analysed to determine the horizontal and vertical angulations in relation to the hamular line and FH plane, respectively. **Results:** The results showed horizontal buccal and palatal safe angulations of 20.8° ± 7.6° and −20.7° ± 8.5° in relation to the hamular line. Maximum and minimum vertical angulations of 61.6° ± 7.0° and 37.2° ± 10.3° were observed, with a mean of 49.8 ± 8.1 in relation to FH plane. The post-operative scans showed that around 98% of the implants placed along the hamular line were successfully engaging the pterygoid plate. **Discussion:** Comparing with the results of previous studies, this study concludes that when implants are placed along the hamular line, they are more likely to engage the centre of the pterygomaxillary junction resulting in an excellent prognosis of pterygoid implants.

Keywords: Basal implants, hamular line, hamular technique, pterygoid implants, pterygomaxillary junction

Introduction

Pterygoid implant was first described by Tulasne and Tessier in the year 1989, to gain the advantage of bone present in the pterygomaxillary region. According to Tulasne, posterior atrophic maxillae preserve around 80% of the original bone corridor, which is adequate for inserting a 13–20 mm long implant.[1]

A pterygoid implant when placed ideally, should engage the pterygomaxillary junction (PMJ), which is formed by the junction of three bones; the dense corticated pterygoid plate of sphenoid bone traversing through the maxillary tuberosity and the pyramidal process of the palatine bone.[2] Previous studies suggested that the angulations of these implants relative to the Frankfort horizontal (FH) plane vary from 45° to 70° anteroposteriorly and 10° to 15° bucco-palatally[2-6] [Table 1]. However, there is no constant point of entry and no anatomical landmark which would guide the clinician in placing the implants in an accurate direction.

The posterior limit of the maxilla is approximated by a small hook-shaped bony process of the sphenoid bone called the hamular process which can be palpated on the posteromedial aspect of the maxillary tuberosity.[7,8] This was taken as the posterior intraoral landmark to engage the PMJ. The distal crest of the maxillary second molar was taken as the anterior landmark, the point of entry of the implants.

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Materials and Methods

Study design

Our study aimed at retrospectively analysing the horizontal angulations of pterygoid implants with respect to the hamular process of the medial pterygoid plate (hamular technique) and vertical angulations relative to the FH plane. The objectives of the study were to measure the height and width of the PMJ, mean angulations on buccal and palatal aspects and vertical angulation with which the implants can be placed without any complications. Ethical committee clearance was waived for the study due to the retrospective nature of the study.

All the cone-beam computed tomography (CBCT) scans were taken using a flat panel detector (Carestream 9300cc). The scans were taken using the exposure parameters of tube potential 90 Kv and tube current of 4.0 ma exposed for 8 s. The Digital Imaging and Communications in Medicine (DICOM) files were then analysed for the parameters using Kodak software.

Study setting

Pre-operative and immediate post-operative CBCT scans of patients who were treated with pterygoid implants between the years 2016 and 2019 in the same private clinic (Dr. Motiwala Dental Clinic and Implant Center) were retrieved and analysed retrospectively. A total of 150 pterygoid implants placed by a single practitioner between the years 2016 and 2019 were included in the study.

Participants

The study sample was selected based on the CBCT scans. All the patients were informed about the study and consent was obtained. Inclusion criteria were patients rehabilitated with pterygoid implants. Scans of patients with intact second molar, which is to be extracted, were included in the study. Those without a post-operative CBCT scan were excluded from the study.

Parameters measured in the cone-beam computed tomography scans

The distal alveolar crest of the maxillary second molar and the tip of the hamular process of the medial pterygoid plate were taken as the two main anatomical landmarks in our study. A line joining these two anatomical landmarks (hamular line) was used as a guide in targeting the PMJ. The following six radiological parameters were recorded in the pre-operative CBCT scans and two parameters in the post-operative scans [Table 2].

Pre-operative cone-beam computed tomography scans

The horizontal range of safety angle along the buccal and palatal extremities of the PMJ from the recommended hamular line was measured along with the width of the PMJ in axial sections [Figure 1].

Parasagittal sections were evaluated to determine the height of the PMJ and the maximum and minimum vertical angulations relative to the FH plane. Mean vertical angulation was derived [Figure 2].

Post-operative cone-beam computed tomography scans

The horizontal angular deviations of the implants along the hamular line were measured in the axial sections of the post-operative scans. Parasagittal sections were evaluated to measure the mean vertical angulations of the implants relative to the FH plane.

Statistical methods

Descriptive and inferential statistics using *t*-test were used to analyse all the parameters was made.

Results

Statistical analysis was done using SPSS (Statistical Package for the Social Sciences, IBM SPSS) version 22. Descriptive

Table 1: Previous studies on angulations of the pterygoid implants

Article	Bucco-palatal/horizontal angulation in axial plane	Vertical angulation in Para-sagittal plane	Vertical angulation in frontal plane	Implant length
Curi *et al*., (2015)[3]	15° oblique to palate	45° to occlusal plane	-	16-20mm
Rodriguez *et al*., (2015)[6]	-	74° to Frankfort plane	81°	15mm
Holtzclaw *et al*., (2018)[16]	-	70° (to occlusal plane)	-	11-13mm
Venturelli *et al*., (1996)[17]	-	45° to maxillary plane	-	-
Candel E *et al*., (2012)[18]	-	35-55°	-	22mm
Ardekian *et al*.,(2018)[19]	-	35-55° (in saggital plane)	-	-

Table 2: Parameters measured in pre-operative and post-operative CBCT scans along different sections

Pre-operative		Post-operative	
Axial sections (Fig I, II, III)	**Parasagittal sections (Fig IV, V)**	**Axial sections (Fig VI)**	**Parasagittal sections (Fig VII)**
Width of PMJ	Height of the PMJ	Angle of the implant placed in relation to the HAMULAR LINE	Angle of the implant placed in relation to FH plane
Buccal safe angle	Maximum vertical safe angle in relation to FH plane		
Palatal safe angle	Minimum vertical safe angle in relation to FH plane		
	Derived mean vertical angulation in relation to FH plane		

PMJ=Pterygomaxillary junction, FH=Frankfort horizontal

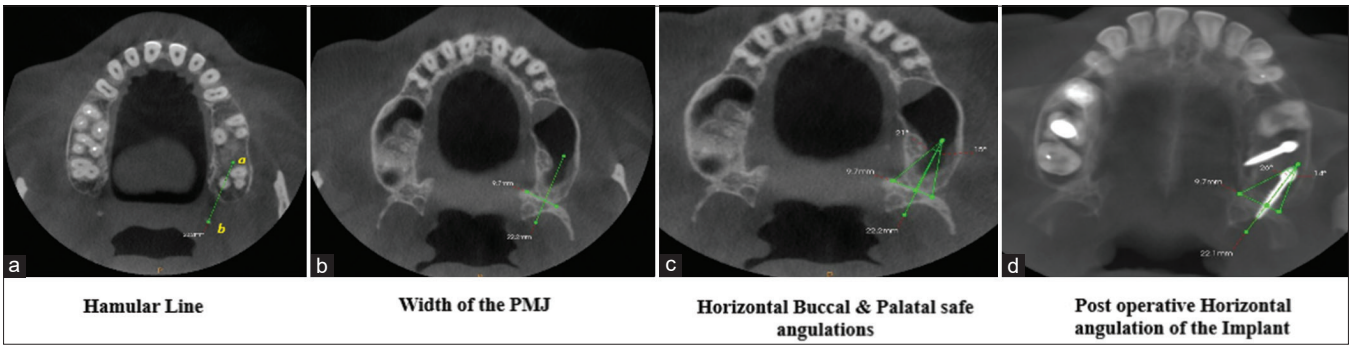


Figure 1: Pre-operative and post-operative horizontal angulations of pterygoid implants in axial view. (a) Hamular line: joining the two anatomical landmarks – (a) distal crest of the second molar and (b) tip of the hamular process as seen in the CBCT at a point where it just appears, (b) width of PMJ: recorded at the first point where the complete fusion of the bones was seen, (c) buccal and palatal safe angle: maximum angle formed by the hamular line with buccal and palatal extremity along the width of the PMJ, and (d) horizontal angulation of implants placed along the hamular line: post-operative CBCT of pterygoid implants engaging the PMJ (axial view). CBCT: Cone-beam computed tomography, PMJ = Pterygomaxillary junction

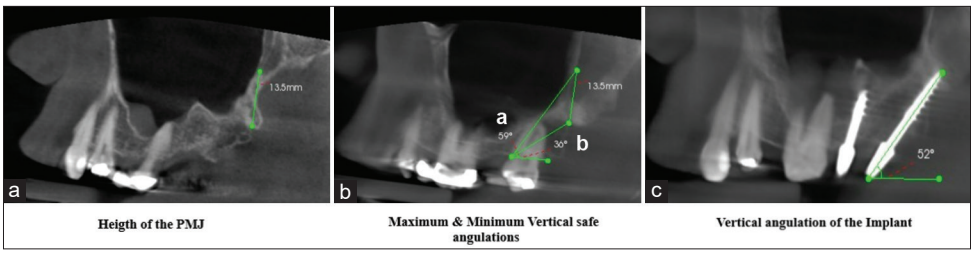
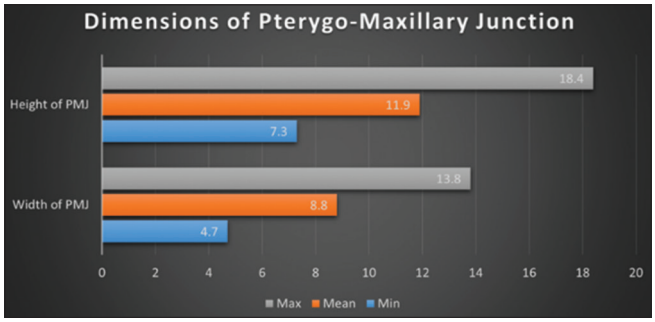


Figure 2: Pre-operative and post-operative vertical angulations of pterygoid implants in parasagittal view (a) height of the PMJ: measured along the junction of all the bones in parasagittal section, (b) maximum and minimum safe angle: (a) angle formed between the highest point of the height of the PMJ and the Frankfort plane (parasagittal view) and b) angle formed between the lowest point of the height of the PMJ and the Frankfort plane (parasagital view), and (c) vertical angulation of implants in relation to FH plane: Post-operative CBCT of Pterygoid implants engaging the PMJ (parasagittal view). CBCT = Cone-beam computed tomography, PMJ = Pterygomaxillary junction



Graph I: Minimum, mean, and maximum dimensions of the height and width of PMJ. PMJ = Pterygomaxillary junction

statistics, paired *t*-tests and independent *t*-tests were performed. The confidence interval was set at 95%. $P < 0.05$ was considered statistically significant.

Most of the patients were in their fifth decade of life, with age ranging between 37 and 74 years. Fifty-four patients from the sample were female and 97 were male. The anatomical and radiological measurements and their analyses are shown in Table 3.

Mean height and width of PMJ at a point with maximum junction of all the bones was 11.9 ± 2.1 mm and 8.8 ± 1.5 mm (± standard deviation) [Graph I].

The mean angle formed between the hamular line and the buccal extremity of the PMJ is 20.8° ± 7.6° and −20.7° ± 8.5°, between the palatal extremity of PMJ and hamular line. Post-operative scans showed a mean horizontal implant angulation of 3° with mean deviations of either −10.4° ± 4.8° on the palatal side or 12.3° ± 6.8° on the buccal side of the hamular line [Graph II].

The maximum and minimum mean vertical safe angulations measured, relative to the FH plane, were 61.6° ± 7.0° and 37.2° ± 10.3°, respectively, with a derived mean value of 49.8° ± 8.1°. Vertical angulations of implants measured in the post-operative scans showed a mean angulation of 54.25° ± 8.56° [Graph III].

The width and average length of the implants used in the pterygoid area were 3.5 mm and 20.39 ± 1.91 mm, respectively.

Paired t-test was used to compare the mean vertical angulations from the pre-operative CBCT scans to those of post-operative angulations of the implants and the results were found to be statistically significant with a $P \leq 0.001$* [Table 4].

When all the parameters were compared between male and female patients, the *P* value was found to be significant for two parameters, i.e., the axial width of the PMJ and vertical angulation.

The results were not statistically significant in relation to rest of the parameters between males and females. Although the study did not aim at analysing the difference between genders,

Table 3: Horizontal and vertical angulations of pterygoid implants in pre-operative and postoperative scan

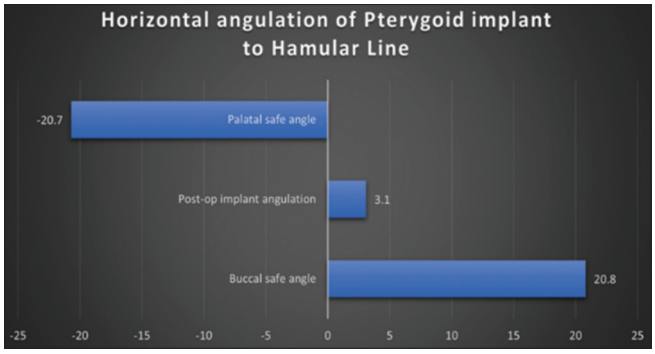
		Variables	Min	Max	Mean	SD
Pre-operative	Axial view	Width of PMJ (mm)	4.7	13.8	8.8	1.5
		Buccal safe angle (°)	6.0	39.0	20.8	7.6
		Palatal safe angle (°)	-5.0	-48.0	-20.7	8.5
	Para-sagittal view	Height of PMJ (mm)	7.3	18.4	11.9	2.1
		Maximum vertical safe angle (°)	42	82	61.6	7.0
		Minimum vertical safe angle (°)	12	65	37.2	10.3
		Derived mean vertical angle (°)	27	70	49.8	8.1
Post-operative	Axial view	Post-op horizontal deviation from the Hamular line (°) (-20 indicates maximum palatal deviation and 34 indicates maximum buccal deviation)	-20	34	3.1	9.6
	Para-sagittal view	Post-op vertical angle (°)	35	78	54.2	7.9
		Length of the implant (mm)	18	24	20.5	1.8

PMJ=Pterygomaxillary junction, SD=Standard deviation

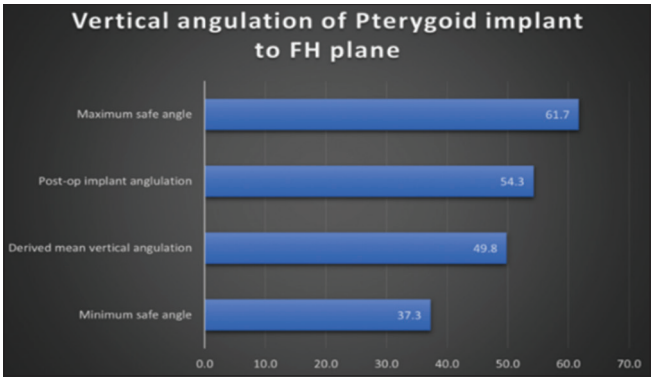
Table 4: Comparison of mean of pre-op mean vertical angle and post-op vertical angle using paired *t*-test

	Mean	*n*	Std. Deviation	Std. Error Mean	*P*
Pre-op mean vertical angle	49.79	151	8.08	0.658	≤0.001*
Post-op vertical angle	54.17	151	7.91	0.644	

*Statistically significant at *P* value <0.01



Graph II: Mean buccal and palatal safe angles and post-operative horizontal angle of the implants



Graph III: Vertical angulation in relation to FH plane and mean post-operative angle of the implants

the results showed that there is not much difference between males and females [Table 5].

Discussion

The use of pterygoid implants eliminated the need for bone augmentation procedures and/or sinus lifting while placing implants in the maxillary retromolar area. They not only help in acquiring great anchorage from the dense pterygoid process but also omit the necessity of distal cantilevers.[6] However, the procedure is highly technique sensitive, owing to the complex anatomy, inadequate access, and although rare, risk of bleeding from the internal maxillary artery.

Although the literature suggests some angulations when placing them, there are no anatomical or radiological landmarks, which can guide in targeting the PMJ. Thus, we have conducted this retrospective radiographic study to give some clinical landmarks, which will guide a clinician in successfully placing a pterygoid implant.

Morphology of pterygomaxillary junction

The PMJ is formed by the fusion of three main bones, which include the posterior part of the maxillary bone, the pyramidal process of the palatine bone and the pterygoid process of the medial pterygoid of the sphenoid bone. This junction presents a very dense cortical bone of around 602.9 to 661.2 density value units, which aids in providing great stability and anchorage to the implants.[6]

Various studies have been performed to know the extensions of the PMJ, most of which are in context to Le Fort I fracture. According to Himani Dadwal *et al*. (2015),[9] Alper Syndel *et al*. (2017)[10] and Yen po chin *et al*. (2017),[11] the mean width of the PMJ was 7.18 ± 1.61 mm, 7.8 ± 1.5 mm and 9.7 ± 1.7 mm, respectively. Carmen Salinas *et al*. (2019)[12] analysed the morphology in relation to pterygoid implants and got a mean width of 7.51 ± 1 mm. Our results showed a mean width of 8.8 ± 1.5 mm and the minor variation in the values can be attributed to the difference in the method of measurement.

Table 5: Comparison of all the variables between males and females using independent *t*-test

	Gender	*n*	Mean	Std. Deviation	Std. Error Mean	*P*
Pre-op						
Axial width of PMJ	Female	54	8.36	1.20	0.16	0.006*
	Male	97	9.07	1.63	0.16	
Axial buccal safe angle	Female	54	20.39	7.57	1.03	0.58
	Male	97	21.10	7.64	0.77	
Axial palatal safe angle	Female	54	20.85	8.58	1.16	0.88
	Male	97	20.64	8.53	0.86	
Parasagittal height of PMJ	Female	54	11.58	2.51	0.34	0.17
	Male	97	12.08	1.86	0.18	
Parasagittal Maximum vertical safe angle	Female	54	61.69	7.70	1.04	0.96
	Male	97	61.63	6.63	0.67	
Parasagittal Minimum vertical safe angle	Female	54	38.04	11.52	1.56	0.48
	Male	97	36.79	9.50	0.96	
Parasagittal Mean vertical safe angle	Female	54	50.11	9.01	1.22	0.72
	Male	97	49.61	7.55	0.76	
Post-op						
Axial angle	Female	54	1.74	10.56	1.43	0.21
	Male	97	3.78	9.00	0.91	
Vertical angle	Female	54	55.91	8.45	1.15	0.04*
	Male	97	53.20	7.46	0.75	
Length of implant	Female	54	20.30	1.66	0.227	0.43
	Male	97	20.54	1.81	0.18	

*Statistically significant at *P* value <0.01, PMJ=Pterygomaxillary junction

The height of the PMJ in our study was 11.9 ± 2.1 mm. According to Himani Dadwal *et al*. (2015),[9] Carmen Salinas *et al*. (2019)[10] and Dong-Yul Kim *et al*. (2013),[13] the mean height was 8.0 ± 1.9 mm, 12.5 ± 1.82 and 13.22 mm, respectively. Alper Syndel *et al*. (2017)[10] measured the length of the junction on dry skulls and got a mean of 15.01 and 15.59 mm on the right and left sides, respectively. Our results are slightly higher when compared to Himani Dadwal *et al*. as they measured the length of the line of fusion between the pterygoid plate and tuberosity, whereas we measured the length of the complete junction of the pterygoid plate with the posterior surface of the maxillary bone.

Placing an implant in the pterygomaxillary area is guided by the individual anatomy of each patient. Moreover, there is no solidarity regarding the ideal position in which pterygoid implants are to be placed. Anatomical studies suggest that in dentulous and edentulous maxillary jaws, the pterygoid pillar is inclined anteroposteriorly at an angle of 67.3° ± 5° and 75.1° ± 3° in relation to the Frankfort plane and bucco-palatally at 17.2° ± 2.7° and 14.1° ± 2.1° against the sagittal plane.[14] Our study aimed at providing the most favourable angulations that help in engaging the dense cortical part of the PMJ with the hamulus being a clinical guide (hamular technique).

Anterior landmark

The point of entry also plays an important role in determining the angulation of pterygoid implants. Studies have been conducted to know the angulation of implants in this region, but only a few suggested that the implants are placed near the first or second molars.[6] The distal alveolar crest of the second molar is the most commonly identifiable hard structure and is located at a mean distance of 10.9 mm from the pterygomaxillary joint when viewed from the lateral aspect.[11]

A more posterior point of entry results in the consequential fabrication of the prosthesis beyond the second molar, resulting in patient discomfort and difficulties in the long run. When placed from the first molar, the prosthesis must be either limited to the first molar or must incorporate a distal cantilever contributing to an imbalanced transmission of occlusal load. The emergence of an implant head near the distal crest of the second molar encompasses the advantage of limiting the distal extension of the prosthetic bridge eliminating these disadvantages.

Hence, the distal crest of the second molar was taken as a constant point of entry.

Posterior landmark

The medial pterygoid plate, originating from the sphenoid bone extends to the posteromedial surface of maxillary tuberosity to form a slender curved hook-like structure called the hamular process.[14,7] The average length of the pterygoid hamulus is around 7.2mm and is longer in older patients.[15] This process is palpable on the posteromedial surface of the maxilla and was taken as the posterior anatomical landmark.[8]

Horizontal angulation

We did not find any studies that have taken hamulus as a reference point in directing the placement of a pterygoid

implant. Our study aimed at utilising the hamular line as a guide in measuring horizontal angulations.

When the angle formed by the hamular line with buccal and palatal extremities of the PMJ was measured, mean values of 20.8° ± 7.6° and 20.7° ± 8.5° were obtained. None of the studies in the literature have so far taken this as a reference angle for measuring the horizontal angulation of pterygoid implants.

Curi *et al*. (2015)[3] gave a horizontal angulation of 15° oblique to the palate in the axial section. Rodriguez *et al*. (2016),[6] in their study, measured the bucco-palatal inclination of pterygoid implants relative to the Frankfort plane in the coronal section and got a mean value of 81.09° ± 2.65°. Our results are not in accordance with any of the previous articles as the reference was different from those studies.

However, there was only a slight variation in the numerical when compared to the anatomical angulation of the pterygoid pillar which was around 17.2° ± 2.7° and 14.1° ± 2.1° in relation to the sagittal plane.[13]

The bucco-palatal angulations in post-operative scans in relation to the hamular line showed that most implants were placed with a buccal deviation of 3° to the hamular line.

Vertical angulations

The vertical angulation was measured relative to the FH plane along the length of the PMJ. The maximum and minimum angulations were measured in the parasagittal sections from the highest and lowest points of the PMJ. Our results showed a minimum and maximum angulation of 37.25° ± 10.2° and 61.70° ± 7.01°, respectively, with a mean of 49.73° ± 8.01°. Various studies proposed a mean vertical angulation of 70° for placing pterygoid implants. None of them, however, gave a range of angulations beyond which a pterygoid implant would miss the PMJ.

Holtzclaw *et al*. (2018)[16] used pterygoid implants in all four techniques and gave a mean mesiodistal angulation of 70.08° ± 7.41° in relation to the occlusal plane. Verturelli *et al*. (1996),[17] Candel *et al*. (2012)[18] and Curi *et al*. (2015),[3] in their studies, suggested mean angulation of around 45° to the maxillary or occlusal plane.

Our results showed a mean implant vertical angulation of 54.25° ± 8.56° against the FH plane. *P* value was found to be statistically significant when pre-operative and post-operative implant angulations were compared. The relative difference in vertical angulations of our study with that of the others can be attributed to the corresponding plane along which the angulations were measured. Furthermore, none of the other studies mentioned a common point of entry for the implants. An implant placed beyond the second molar may subsequently have greater angulation, whereas that placed near the first molar may have lesser vertical angulation. Our study standardised the point of entry by taking the distal crest of the second molar as a constant point of insertion for all the implants.

Considering the length of implants to be used in this region, various studies proposed the length of a pterygoid implant can range from 15 to 22 mm[11,12,17,19] with 18 mm being the most commonly used one. The mean length of the implants that were used in our study was 20 mm with only a few cases of shorter lengths. All the implants had a common width of 3.5 mm at the point of engaging the pterygoid plate.

Pterygoid implants although prove to be a good alternative in many patients with atrophic maxilla; their placement is relatively difficult due to the anatomical complexity. Our study did not use any surgical guide and adopted the technique using anatomical landmarks. These landmarks gave an exact direction in which these implants can be placed with no complications and a good prognosis.

Conclusion

Our study concludes that taking the distal crest of the second molar as the point of entry, an implant when placed along the hamular line with a vertical angulation of 49.73 ± 8.01° to Frankfort horizontal plane aims the pterygoid plate and aids in successfully engaging the cortical bone without any complications.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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