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Assessment of interradicular space of the posterior palatal alveolar process for orthodontic mini-implant in different facial morphological pattern - a prospective study.

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ABSTRACT

Background:Orthodontic mini-implants, commonly referred to as temporary anchorage devices, provide reliable skeletal anchorage and have become an important component of contemporary orthodontic treatment. Successful placement of these devices requires adequate interradicular space and sufficient cortical bone thickness to avoid root injury and ensure primary stability. Cone-beam computed tomography allows precise three-dimensional evaluation of alveolar bone morphology and has become a valuable tool for identifying safe insertion sites for orthodontic mini-implants.

Objective:To evaluate the interradicular distance and the distance from the palatal cortical bone surface to the narrowest interradicular space in the posterior palatal alveolar process between the maxillary second premolar and 1st molars among individuals with different facial growth patterns using CBCT imaging.

Materials and Methods: This retrospective CBCT-based study analysed images obtained from individuals categorized according to facial growth patterns. Measurements of interradicular distance and the distance from the palatal cortical bone surface to the narrowest interradicular space were recorded at multiple vertical levels from the cemento-enamel junction in the posterior palatal interdental region between the maxillary second premolar and 1st molars. Statistical analysis was performed to evaluate variations among different vertical levels and facial growth patterns.

Results:Both interradicular distance and the distance from the palatal cortical bone surface to the narrowest interradicular space increased progressively with increasing distance from the CEJ. The region located approximately 6–8 mm apical to the CEJ demonstrated the greatest interradicular space and cortical bone engagement, indicating favourable anatomical conditions for orthodontic mini-implant placement.

Conclusion:The posterior palatal interdental region between the maxillary 2nd premolar and 1st molars at approximately 6–8 mm apical to the CEJ represents the most favourable site for orthodontic mini-implant placement. Preoperative CBCT evaluation is recommended to accurately assess interdental bone morphology and identify safe insertion zones, thereby minimising the risk of root proximity and improving the stability of temporary anchorage devices.

INTRODUCTION

Anchorage control has been transformed by orthodontic mini-implants, which offer complete anchorage with little surgical morbidity and patient compliance. However, proper cortical bone thickness and interradicular space at the insertion site are critical to their clinical effectiveness. Failure, instability, or injury to the roots might arise from improper placement. Thus, before inserting a mini-implant, a thorough three-dimensional evaluation of the morphology of the alveolar bone is necessary.

The gold standard for assessing dentoalveolar structures pertinent to the insertion of temporary anchoring devices is cone-beam computed tomography (CBCT). There is a notable variance in the posterior maxilla's palatal bone thickness and interradicular space, highlighting the need of vertical level measurement.[1] Skeletal traits and anatomical location affect both interradicular distance and cortical bone thickness.[2,3] There is a progressive widening of the interradicular spaces toward the apex.[4,5] One important factor influencing primary stability is cortical bone thickness.[6,7]

Alveolar bone properties may be influenced by face morphological patterns in addition to site-specific anatomy. Variations in cortical thickness, bone density, and root proximity have been linked to skeletal divergence. Differences in alveolar morphology have been observed across various facial types.[8] Hyperdivergent individuals exhibit reduced cortical thickness compared to hypodivergent subjects.[9,10] Vertical growth patterns significantly influence maxillary bone dimensions.[11] These findings suggest that mini-implant planning should consider individual facial morphology to optimize clinical outcomes.

Additional evaluations have identified anatomically favorable palatal insertion zones for mini-implants.[12],[13,14] Bone morphology has been associated with the success rates of mini-implants.[15 ,16] When taken as a whole, these studies demonstrate how crucial CBCT-based anatomical mapping is for locating secure and stable insertion sites.

Previous studies have established the reproducibility of CBCT readings for alveolar bone assessment and the reliability of CBCT in assessing interradicular space and cortical bone thickness.[17] When it comes to measuring interradicular dimensions, three-dimensional imaging shows excellent accuracy.[18] Additionally, minimal interradicular clearance and sufficient cortical engagement are emphasized as requirements for mini-implant stability in systematic research and clinical guidelines. Careful preoperative radiographic evaluation is essential to reduce complications and improve success rates.[19 ,20]

There is a dearth of research that particularly addresses interradicular space measurement in the posterior palate alveolar process across various facial morphological patterns with balanced gender distribution, despite numerous CBCT-based anatomical studies and established therapeutic recommendations. A thorough assessment is necessary due to the possible impact of skeletal divergence on the morphology of alveolar bones.

In order to evaluate the interradicular space of the posterior palate alveolar process at several vertical levels, the current prospective study will use CBCT on participants with vertical, horizontal, and straight face morphological patterns. The results could offer therapeutically useful recommendations for the safe and reliable insertion of orthodontic mini-implants.

MATERIALS AND METHODS

CBCT scans of all subject collected from Peoples University, Bhopal, Madhya Pradesh, India and then examination of facial morphologic pattern and interradicular safe zone is evaluated. Based on their vertical face pattern and absence of sagittal malocclusion, the subjects were divided into one of three groups using lateral cephalograms created from the CBCTs. The angle created by the following cephalometric measures was used to determine these facial patterns:(Fig 1)
1) Mandibular plane: the angle formed by the mandibular plane (gonion to menton) and the anterior cranial base (sella to nasion)
2) The face height index, which is calculated by dividing the distance from sella (S) to gonion (Go) by the distance from nasion (N) to menton (Me), is the ratio of posterior to anterior face height.

Inclusion criteria included patients aged between 18 and 30 years with fully erupted permanent dentition, excluding third molars. Exclusion criteria included patients with cleft palate, missing or supernumerary teeth, a history of previous orthodontic treatment, or the presence of impacted teeth in the palatal region. Sample size consisting of 90 orthodontic patients out of which 30 samples will be of Average, Horizontal and Vertical facial morphological pattern each. They are further subdivided in two group on basis of gender i.e 15 male and 15 female in each group. A CBCT scan projection of patients will be obtained with parameter of: voxel size 0.3 mm, voltage-120kvp, current-6.3mA and FOV of 12*10. Image assessment will be done in dim light with help of Care Stream 9600 CBCT scanner. CS 3d imaging v3.10.21 Software will be used to measure inter radicular safe zone. Sagittal images between the maxillary second premolar and the first molar area that passed through the middle of the two teeth were created in order to measure the interradicular distance and the distance to the narrowest interradicular space from the cortical bone surface. Next, five axial polyline from the cemento enamel junction (CEJ) apically and parallel to the root of second premolar were created at 2-mm intervals (Fig. 2). At each axial plane, the smallest interradicular distance between adjacent root surfaces was measured (Fig. 3,A). We moved 2 mm apically to measure it. Next, moving 2 mm apically, the distance between the palatal cortical bone surface and the narrowest interradicular space was measured in the same axial plane (Fig. 3,B).

All statistical analyses were performed using SPSS software (version v 23.0 IBM Corp., USA). Descriptive statistics including mean and standard deviation (SD) were calculated for Narrowest Interradicular Distances and palatal cortical bone thickness. Intergroup comparisons among the three facial morphological patterns (horizontal, vertical, and average) were performed using one-way analysis of variance (ANOVA). Analysis of variance (ANOVA) and a multivariable comparison with the Duncan multiple range test (MRT) were used to compare differences in the narrowest interradicular distances, and the distances between the cortical-bone surface and the narrowest interradicular space in the sequential axial planes. Independent sample t-tests were used to evaluate gender differences within each growth pattern. A p-value <0.05 was considered statistically significant.

Figure 1: Measurements of facial patterns: 1) Anterior cranial base (sella [S] to nasion [N]) and mandibular plane (gonion to menton), 2) Face height index, the ratio of posterior face height to anterior face height using the measurements of distance from sella (S) to gon ion (Go) divided by the distance of nasion (N) to menton (Me).

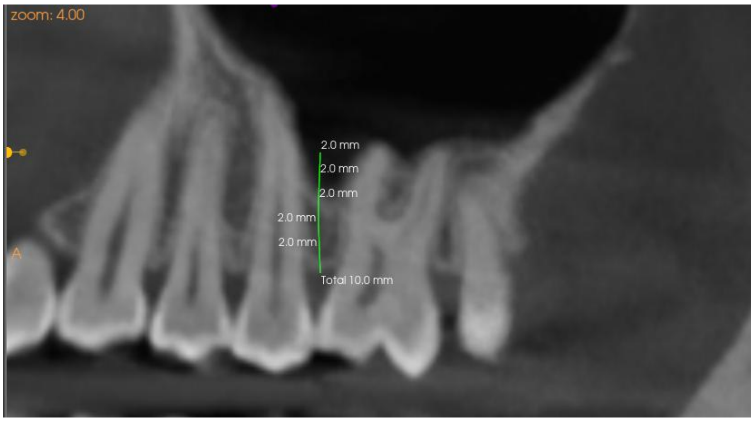


Fig 2. Sagittal view of the maxillary CBCT image. Sequential polyline between interdental space of the maxillary second premolar and the first molar in 2-mm intervals, 0 to 10 mm from the CEJ.

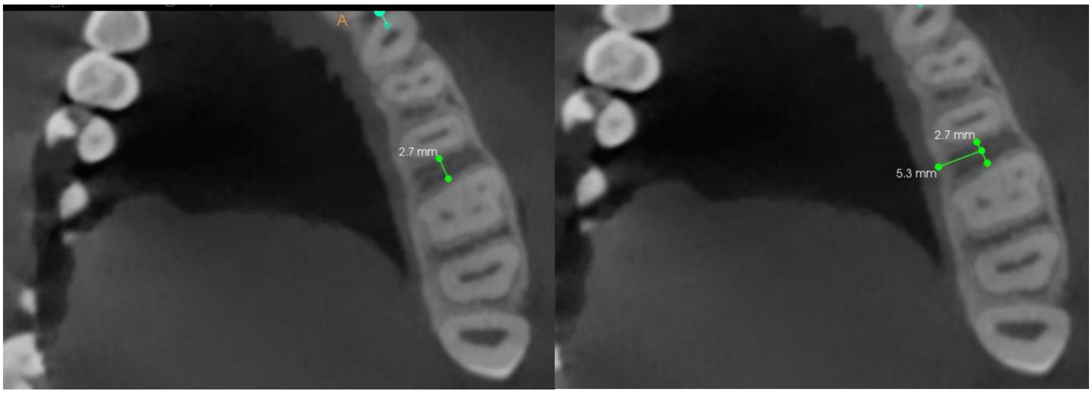


Fig 3. A, Measurement of the narrowest interradicular distance; B, distance between the cortical bone surface and the narrowest interradicular space.

RESULTS

Interradicular Distance and the distance to the narrowest interradicular space from the palatal cortical bone surface in Males

The results demonstrated that both distance to the narrowest interradicular space from the palatal cortical bone surface and interradicular distance increased progressively with increasing distance from the CEJ shown in Table 1. Among the three facial growth patterns, individuals with horizontal growth pattern exhibited comparatively greater interradicular distance, followed by the average growth pattern, while the vertical growth pattern showed relatively reduced measurements. Statistical analysis using one-way ANOVA revealed significant differences among the growth patterns at certain levels from the CEJ ($p < 0.05$), suggesting that facial morphology influences the available interradicular space for mini-implant placement.

Interradicular Distance and the distance to the narrowest interradicular space from the palatal cortical bone surface in Females

Similar to the male group, interradicular distance and the distance to the narrowest interradicular space from the palatal cortical bone surface in Females increased with increasing vertical distance from the CEJ. It is presented in Table 2. However, females demonstrated slightly lower mean values compared with males in most measured regions. Statistical evaluation indicated significant differences between the facial growth patterns at specific levels from the CEJ ($p < 0.05$), indicating that growth pattern also influences palatal bone morphology in females.

Gender Differences in Average Growth Pattern

The comparison of anatomical parameters between male and female subjects with an average growth pattern is summarized in Table 3. Males generally demonstrated higher mean values of interradicular distance and the distance to the narrowest interradicular space from the palatal cortical bone surface in Males than females at most measurement levels. However, statistically significant gender differences were observed only at selected distances from the CEJ ($p < 0.05$), while other levels did not show statistically significant differences.

Gender Differences in Horizontal Growth Pattern

Table 4 illustrates the comparison between male and female subjects with a horizontal growth pattern. The horizontal growth pattern showed relatively greater interradicular space compared to other facial types, suggesting a favourable anatomical environment for orthodontic mini-implant placement. Although males showed higher mean measurements than females, the difference was statistically significant only at certain levels from the CEJ ($p < 0.05$).

Gender Differences in Vertical Growth Pattern

The comparison of anatomical parameters between males and females with a vertical growth pattern is shown in Table 5. Subjects with a vertical growth pattern exhibited reduced interradicular distance and cortical bone thickness compared with the horizontal and average growth patterns. Gender comparison demonstrated slightly greater measurements in males, but the difference was not statistically significant at most levels ($p > 0.05$).

Summary of Findings

The distance from the palatal cortical bone surface to the narrowest interradicular space increased significantly as measurements moved apically from the CEJ.

The narrowest interradicular distance also showed a progressive increase from 2 mm to 10 mm from the CEJ.

Males generally demonstrated higher mean values of interradicular distance and the distance to the narrowest interradicular space from the palatal cortical bone surface in Males than females at most measurement levels. However, statistically significant gender differences were observed only at selected distances from the CEJ

Individuals with horizontal growth pattern exhibited comparatively greater interradicular distance and the distance to the narrowest interradicular space from the palatal cortical bone surface, followed by the average growth pattern, while the vertical growth pattern showed relatively reduced measurements.

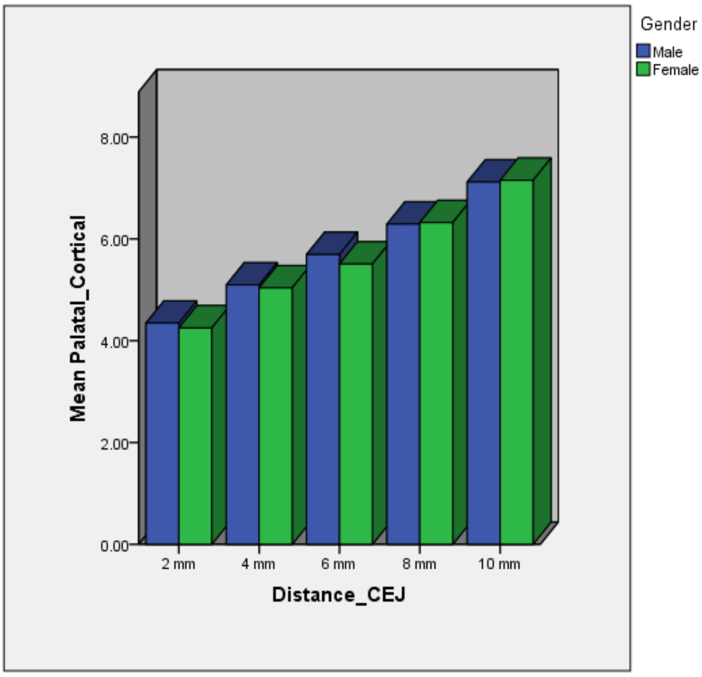
Table 1: Distance from the palatal cortical bone surface to the narrowest interradicular space and interradicular distance at different levels from the CEJ among various male growth patterns

Growth Pattern	Distance from CEJ	Palatal_Cortical		P value	Interdental		P value
		Mean	Standard Deviation		Mean	Standard Deviation	
Average	2 mm	4.04	.62	<0.001**	1.79	.36	<0.001**
	4 mm	4.78	.58		2.46	.53	
	6 mm	5.42	.70		2.93	.53	
	8 mm	5.98	.88		3.53	.82	
	10 mm	7.07	.90		4.34	1.30	
Horizontal	2 mm	4.73	.78	<0.001**	2.39	.74	<0.001**
	4 mm	5.41	1.07		2.59	.39	
	6 mm	5.99	.76		3.04	.86	
	8 mm	6.67	1.37		3.96	1.12	
	10 mm	7.21	2.05		5.16	1.69	
Vertical	2 mm	4.27	.68	<0.001**	1.87	.34	<0.001**
	4 mm	5.10	.77		2.43	.36	
	6 mm	5.67	.97		2.67	.32	
	8 mm	6.23	1.39		3.41	.80	
	10 mm	7.07	1.85		4.45	.92	

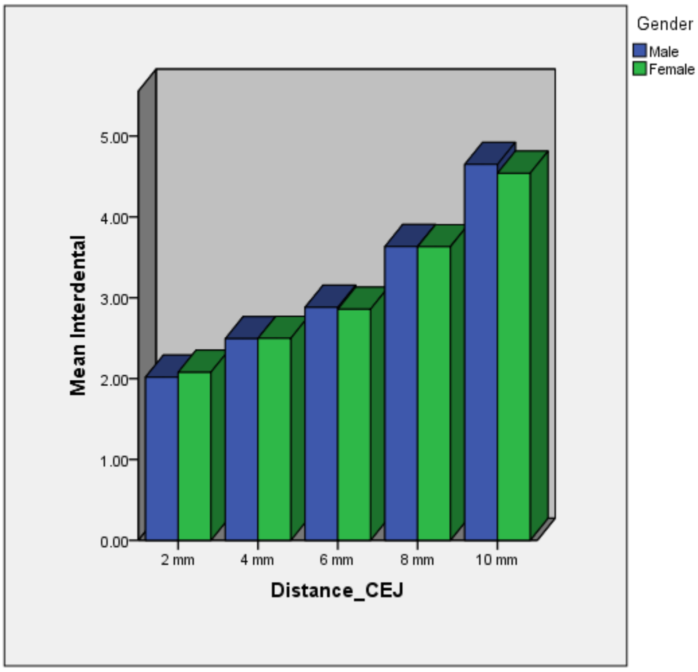
Table 2: Distance from the palatal cortical bone surface to the narrowest interradicular space and interradicular distance at different levels from the CEJ among various female growth patterns

Growth Pattern	Distance from CEJ	Palatal_Cortical		P value	Interdental		P value
		Mean	Standard Deviation		Mean	Standard Deviation	
Average	2 mm	4.07	.80	<0.001**	1.84	.39	<0.001**
	4 mm	4.76	.70		2.44	.48	
	6 mm	5.05	.80		2.64	.48	

	8 mm	6.03	1.10		3.21	.66	
	10 mm	6.75	1.55		3.51	1.23	
Horizontal	2 mm	4.34	.79	<0.001**	2.45	.34	<0.001**
	4 mm	5.17	.77		2.63	.34	
	6 mm	5.73	.90		2.95	.90	
	8 mm	6.39	.81		3.61	1.31	
	10 mm	7.12	1.42		4.93	1.71	
Vertical	2 mm	4.35	.60	<0.001**	1.94	.37	<0.001**
	4 mm	5.18	.77		2.42	.69	
	6 mm	5.73	.95		2.98	.80	
	8 mm	6.54	1.02		4.07	1.14	
	10 mm	7.58	1.63		5.18	1.46	



Graph 1: The comparison of the distances between the palatal cortical-bone surface and the narrowest interradicular space among various distances from CEJ among genders



Graph 2: The comparison of the narrowest interradicular distances among various distances from CEJ among genders

Table 3: The comparison of Interradicular distance and distance from the palatal cortical bone surface to the narrowest interradicular space distances with gender in average growth pattern

Distance from CEJ	Gender	Palatal_Cortical		P value	Interdental		P value
		Mean	Standard Deviation		Mean	Standard Deviation	
2 mm	Male	4.04	.62	0.919	1.79	.36	0.736
	Female	4.07	.80		1.84	.39	
4 mm	Male	4.78	.58	0.932	2.46	.53	0.915
	Female	4.76	.70		2.44	.48	
6 mm	Male	5.42	.70	0.192	2.93	.53	0.122
	Female	5.05	.80		2.64	.48	
8 mm	Male	5.98	.88	0.884	3.53	.82	0.248
	Female	6.03	1.10		3.21	.66	
10 mm	Male	7.07	.90	0.494	4.34	1.30	0.084
	Female	6.75	1.55		3.51	1.23	

Table 4: The comparison of Interradicular distance and distance from the palatal cortical bone surface to the narrowest interradicular space distances with gender in Horizontal growth pattern

Distance from CEJ	Gender	Palatal_Cortical		P value	Interdental		P value
		Mean	Standard Deviation		Mean	Standard Deviation	
2 mm	Male	4.73	.78	0.181	2.39	.74	0.776
	Female	4.34	.79		2.45	.34	
4 mm	Male	5.41	1.07	0.499	2.59	.39	0.732
	Female	5.17	.77		2.63	.34	
6 mm	Male	5.99	.76	0.402	3.04	.86	0.789
	Female	5.73	.90		2.95	.90	
8 mm	Male	6.67	1.37	0.501	3.96	1.12	0.434
	Female	6.39	.81		3.61	1.31	
10 mm	Male	7.21	2.05	0.894	5.16	1.69	0.710
	Female	7.12	1.42		4.93	1.71	

Table 5: The comparison of Interradicular distance and distance from the palatal cortical bone surface to the narrowest interradicular space distances with gender in vertical growth pattern

Distance from CEJ	Gender	Palatal_Cortical		P value	Interdental		P value
		Mean	Standard Deviation		Mean	Standard Deviation	
2 mm	Male	4.27	.68	0.735	1.87	.34	0.576
	Female	4.35	.60		1.94	.37	
4 mm	Male	5.10	.77	0.779	2.43	.36	0.947
	Female	5.18	.77		2.42	.69	
6 mm	Male	5.67	.97	0.851	2.67	.32	0.178
	Female	5.73	.95		2.98	.80	
8 mm	Male	6.23	1.39	0.488	3.41	.80	0.074
	Female	6.54	1.02		4.07	1.14	
10 mm	Male	7.07	1.85	0.432	4.45	.92	0.111
	Female	7.58	1.63		5.18	1.46	

DISCUSSION

Temporary anchoring devices are a crucial part of contemporary orthodontic biomechanics because they offer complete anchorage with little need on patient compliance and rather easy surgical techniques.[1] In order to prevent root damage and guarantee primary stability, orthodontic mini-implants' clinical success is mostly dependent on appropriate site selection, acceptable cortical bone thickness, and sufficient interradicular space.[1]

The most consistent imaging technique for assessing dentoalveolar structures pertinent to mini-implant placement is generally acknowledged to be cone-beam computed tomography.[1] There have also been reports of variations in interradicular bone width across people with various growth patterns, which could affect the availability of safe zones for miniscrew installation.[4] Interradicular distance tends to rise as the measuring point travels apically from the cemento-enamel junction , according to CBCT investigations of interdental gaps in the posterior maxilla. These results are in line with the current study's findings, which showed that as distance from the CEJ increases, so does interradicular distance and the distance between the palatal cortical bone surface and the narrowest interradicular space. Three-dimensional CBCT assessments of alveolar bone morphology have also revealed similar patterns of increased interradicular width near the root apex.[5,6]

Facial growth patterns may also affect the anatomical features of palatal bone. Previous CBCT research has indicated notable differences in palatal bone thickness among individuals with varying facial types, implying that skeletal morphology could affect the stability of orthodontic mini-implants.[7,8] Furthermore, other research has shown that individuals with vertical growth patterns often have decreased cortical bone thickness, potentially impacting the stability of orthodontic mini-implants.[9] Recent CBCT analyses have also validated that vertical facial types usually exhibit lower alveolar bone thickness in comparison to horizontal facial types.[10] Additional studies have documented differences in palatal bone thickness among individuals with diverse facial patterns, emphasizing the necessity for tailored treatment planning prior to miniscrew insertion.[11]

Numerous research efforts have sought to determine the best anatomical locations for placing orthodontic mini-implants. CBCT assessments of possible insertion sites have shown that the posterior interdental areas could offer beneficial bone dimensions for miniscrew insertion.[12,13] Additional CBCT studies have underscored the importance of assessing palatal bone height and thickness prior to mini-implant placement to guarantee safe and stable anchorage.[14] Computed tomographic examinations of alveolar bone containing teeth have revealed notable differences in bone thickness across various interdental areas.[15] Furthermore, studies assessing bone mineral density have indicated that the quality of bone significantly influences the clinical stability of orthodontic mini-implants.[16]. Research has verified the accuracy and reliability of CBCT imaging in assessing alveolar bone height and thickness.[17,18]Systematic reviews assessing interradicular locations for miniscrew placement have indicated that the presence of cortical bone thickness and interdental space differs based on the vertical level from the alveolar crest. The posterior maxillary interdental areas might offer appropriate conditions for miniscrew insertion but necessitate thorough assessment to prevent root proximity.[19] Additionally, mechanical aspects like insertion torque have been noted to affect the stability and effectiveness of orthodontic mini-implants.[20] Temporary anchorage devices in orthodontics have emerged as a crucial part of contemporary orthodontic biomechanics since they offer absolute anchorage with minimal dependence on patient cooperation. Clinical studies have indicated positive success rates when miniscrew implants are inserted with suitable surgical methods and anatomical awareness.[21] The advent of orthodontic micro-implants has broadened the clinical uses of skeletal anchorage in orthodontic care.[22] Initial clinical findings showed that miniscrews can effectively deliver temporary skeletal anchorage for numerous orthodontic tooth movements.[23]

The advent of CBCT imaging has greatly enhanced clinicians' capacity to assess anatomical structures prior to implant placement. CBCT enables precise visualization of bone structure and adjacent anatomical features, thus aiding in detailed treatment planning for the placement of orthodontic mini-implants[24]. Research has shown that the correct insertion angle and adequate engagement with cortical bone are crucial elements affecting the success rate of screw implants utilized for orthodontic support.[25]

Based on the CBCT measurements obtained in the present study, the posterior palatal interdental region between the maxillary second premolar and first molars can be categorized into danger, caution, and safe zones depending on the available interradicular space. The red zone (2–4 mm apical to the CEJ) represents a danger zone where interradicular distance is limited and the risk of root proximity is high. The yellow zone (4–6 mm apical to the CEJ) represents a caution zone where moderate interradicular clearance may be present and careful radiographic evaluation is required. The green zone (approximately 6–8 mm apical to the CEJ) represents the safest region, where increased root divergence and greater cortical bone engagement provide favorable conditions for mini-implant stability.[26]

Insertion angulation also plays an important role in determining the safety of orthodontic mini-implant placement. When approximately 6 mm of the screw engages the bone, insertion at 30° provides a horizontal clearance of approximately 5.19 mm, whereas insertion at 45° provides approximately 4.24 mm of clearance. In contrast, insertion at 60° reduces the horizontal clearance to approximately 3 mm, thereby increasing the risk of root proximity. Therefore, an insertion angulation of approximately 30–45° relative to the occlusal plane is considered optimal because it enhances cortical bone engagement while maintaining adequate distance from adjacent roots.[27]

Another important anatomical consideration in the posterior maxilla is the proximity of the maxillary sinus and the greater palatine neurovascular bundle. Placement of mini-implants too far apically may increase the risk of sinus perforation, particularly when insertion occurs beyond 8–11 mm from the alveolar crest.[28] Excessively posterior placement may also approach the greater palatine artery and nerve, which may result in bleeding or nerve irritation. Therefore, careful radiographic assessment and appropriate selection of insertion sites remain essential for ensuring safe and successful orthodontic mini-implant placement.[29]

CONCLUSION

In this CBCT-based study, the interradicular distance and the distance from the palatal cortical bone surface to the narrowest interradicular space in the posterior palatal alveolar process were observed to progressively increase with greater vertical distance from the cemento-enamel junction. These results suggest that higher apical areas offer increased bone availability for the placement of orthodontic mini-implants.

The posterior palatal interdental area located between the maxillary second premolar and first molars can be clinically classified into danger (2–4 mm), caution (4–6 mm), and safe zones (6–8 mm apical to the CEJ) depending on the available interradicular space. Among these areas, the 6–8 mm apical zone serves as the optimal location for mini-implant insertion, as it allows for increased interradicular space and enhanced cortical bone contact.

Consequently, meticulous CBCT assessment of interdental bone structure is crucial for correctly identifying safe insertion areas, allowing practitioners to reduce the risk of root proximity and enhance the stability and effectiveness of orthodontic temporary anchorage devices..

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