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Original Research Article

RELATION OF MAXILLARY SINUS FLOOR AND ROOT APICES OF MAXILLARY FIRST MOLAR IN SAGITTAL AND VERTICAL SKELETAL PATTERNS USING CONE BEAM COMPUTED TOMOGRAPHY SCANNING

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ABSTRACT

Background: *The anatomical proximity between the maxillary sinus floor (MSF) and the root apices of the maxillary first molar has important clinical implications for endodontic, orthodontic, and surgical procedures. Variations in skeletal patterns may influence this relationship, potentially affecting treatment outcomes.* ***Objective:*** *To determine the correlation between the distances from the root apices of the maxillary first molar to the maxillary sinus floor on cone beam computed tomography (CBCT) in different sagittal and vertical skeletal patterns.* ***Study Design:*** *Cross-sectional study.* ***Setting:*** *Department of Orthodontics, Fatima Memorial Hospital, Lahore, Pakistan.* ***Duration of Study:*** *From 16th November 2024 to 16th May 2025.* ***Methods:*** *A total of 41 patients aged 18–50 years of both genders were included. Subjects had fully developed and intact maxillary first molars with no history of orthodontic treatment, trauma, surgery, or craniofacial deformities. Patients with dental anomalies, syndromes, or root resorption were excluded. Participants were classified into sagittal (Class I, II, III) and vertical (hypo-, normo-, hyperdivergent) skeletal patterns. CBCT scans were analyzed using NNT software to measure the vertical distances from the mesiobuccal, distobuccal, and palatal root apices to the MSF. Data were analyzed using Spearman's correlation to assess associations with ANB and SN-MP angles.* ***Results:*** *The mean age of participants was 34.46 ± 9.74 years; 24 (58.5%) were male and 17 (41.5%) female. Most had Class I sagittal (48.8%) and normodivergent vertical (68.3%) skeletal patterns. The mesiobuccal root was closest to the MSF (3.33 ± 1.69 mm), followed by the distobuccal (3.49 ± 2.07 mm) and palatal roots (2.38 ± 1.97 mm). No statistically significant correlation was found between root–MSF distances and sagittal or vertical skeletal patterns ($p > 0.05$).* ***Conclusion:*** *There was no significant correlation between the root apices of the maxillary first molar and the maxillary sinus floor across sagittal or vertical skeletal patterns. The mesiobuccal root was the closest to the MSF, and younger patients tended to have shorter root–sinus distances.*

Keywords: Maxillary Sinus Floor, Maxillary First Molar Roots, Skeletal Patterns, CBCT, ANB Angle, SN-MP Angle

INTRODUCTION

The maxillary sinus, also referred to as Highmore's antrum, is the largest paranasal sinus situated within the maxilla. By the age of 9 years, the Maxillary Sinus Floor (MSF) aligns with the floor of the nasal cavity. In cases of enlarged maxillary sinuses, the MSF may extend beyond the nasal floor, leading to contact or protrusion of premolar and molar roots into the sinus cavity. The positioning of posterior teeth relative to the sinus is contingent upon the size of the maxillary sinus (1).

The maxillary sinus is a significant anatomical structure in the midface region. Advancements in modern dentistry, particularly implantation, underscore the necessity for a comprehensive understanding of its anatomical features, including sinus borders, sinus floor septa, and the relationship between molar roots and the sinus floor (2). This anatomical relationship plays a crucial role in planning dental implantation, tooth extraction, and endodontic procedures. It varies with age, as well as the size and degree of pneumatization of the maxillary sinus. In some cases, the sinus floor may have only a single layer of mucous or cortical bone, heightening the risk of oroantral fistula or sinus infection. Therefore, precise identification of the proximity and thickness of mucosa and cortical bone between root apices and the Maxillary Sinus Floor (MSF) is imperative for surgical interventions (3, 4).

The simplest way to evaluate the relationship between molar root apices and the Maxillary Sinus Floor (MSF) is through proper imaging. Cone-beam computed tomography (CBCT) is a commonly employed technique for this purpose (5). CBCT, a three-dimensional (3D) imaging method, enhances clinical Diagnosis and treatment planning by providing precise evaluations of anatomical structures. It has been noted for its effectiveness in assessing the relationship between maxillary posterior tooth roots and the maxillary sinus. Numerous studies have utilized CBCT to examine the proximity of maxillary posterior teeth to the MSF (5, 6).

Studies have yielded varied conclusions regarding the correlation between different skeletal patterns. For instance, Kosumarl et al. found no significant difference in the distance from maxillary root apices to the Maxillary Sinus Floor (MSF) between skeletal open bite and skeletal normal bite cases (7). In another study by Shrestha B et al., which utilized CBCT, a positive correlation (i.e., $r > 0.922$) was observed between the distances from posterior root apices to the MSF across different skeletal patterns (1). Specifically, in the vertical skeletal pattern, the distances of the first molar palatal root to the MSF were 0.90 ± 3.60 mm in high-angle cases, 1.95 ± 3.18 mm in low-angle cases, and 2.46 ± 4.92 mm in normal-angle cases. Regarding the anteroposterior skeletal pattern, these distances were 1.94 ± 3.52 mm in Class I, 0.77 ± 3.08 mm in Class II, and 2.72 ± 5.02 mm in Class III patterns. Overall, the mean distance observed was 1.78 ± 4.01 mm (1).

This study represents a pioneering effort within our local setting, as no similar research had been conducted previously in our population. While a few nationwide studies have explored correlations between maxillary root apices and the sinus floor in various skeletal patterns (4, 8), further research is needed to understand these connections. The findings of this study will establish fundamental data for dental surgeons and will enhance diagnostic accuracy and treatment planning strategies for maxillary posterior teeth.

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METHODOLOGY

This was a cross-sectional study conducted at the Department of Orthodontics, Fatima Memorial Hospital, Lahore. The duration of this study was six months, from November 16, 2024, to May 16, 2025. A total of 41 patients were enrolled, based on the expected correlation between the distances from posterior root apices to the MSF in different skeletal patterns (r = 0.922) from a previous study, with an expected precision of 5% and a confidence level of 95%. The sample size was calculated through Pearson's Correlation estimation calculator.9 Non-probability consecutive sampling approach was applied.

Patients of both genders, aged 18-50 years, with completely formed maxillary first molars, no missing maxillary first molars, no history of orthodontic treatment, no history of facial trauma or surgery, and no history of congenital facial deformities were included. Patients with significant dental anomalies of number, size, and form, craniofacial syndromes and facial asymmetries, a history of trauma, root canal-treated teeth, resorbed roots, and incomplete root formation were excluded to avoid bias in the study results.

All patients were categorized into three classes at the time of clinical diagnosis based on sagittal skeletal pattern: Class I (ANB = 0° to 4°), Class II (ANB > 4°), and Class III (ANB < 0°). These patients were further diagnosed based on vertical divergence: Hyperdivergent (SN-MP > 36°), Normodivergent (SN-MP 28°-36°), and Hypodivergent (SN-MP < 28°). Cone-beam computed tomography (CBCT) was used to obtain a lateral view, which served as a lateral cephalogram. The vertical relationships between the root apices of the maxillary first molar (mesiobuccal, distobuccal, and palatal roots) and the maxillary sinus floor (MSF) were classified into three types to determine distances for each root apex: Type-I, if the root apex was below the inferior wall of the maxillary sinus; Type-II, if the root apex was in contact with it; and Type-III, if the root apex projected into the sinus. Distance measurements from root apices to MSF were performed using NNT software version 5.3.0.0. All related data, including demographic details such as age, gender, address, education level, and contact information, were recorded for data analysis in SPSS version 23. Mean ± SD were calculated for quantitative variables, whereas frequencies and percentages were calculated for categorical variables. The Spearman correlation test was applied to determine the correlation between root apex distances and skeletal patterns. Effect modifiers like age, gender, and education level were controlled through stratification. Post-stratification chi-square test was applied, considering $P \leq 0.05$ as significant.

RESULTS

Table 1 presents the mean and standard deviation of quantitative variables. The average age of the participants was 34.46 ± 9.74 years. The ANB angle had a mean of 1.80 ± 2.69. The SN-MP angle was 31.83 ± 4.26. The distance from the mesiobuccal root to the MSF was 3.33 ± 1.69 mm, from the distobuccal root to the MSF was 3.49 ± 2.07 mm, and from the palatal root to the MSF was 2.38 ± 1.97 mm.

Table 1: Mean ± Standard Deviation of Quantitative Variables

Quantitative Variables	Mean ± Standard Deviation
Age (years)	34.46 ± 9.74
ANB (degree)	01.80 ± 2.69
SN-MP (degree)	31.83 ± 4.26
Mesiobuccal to MSF Distance (mm)	03.33 ± 1.69
Distobuccal to MSF Distance (mm)	03.49 ± 2.07
Palatal to MSF Distance (mm)	02.38 ± 1.97

Table 2 presents the frequencies and percentages of qualitative variables. Among the age groups, 17 participants (41.5%) were between 18 and 30 years, 11 (26.8%) were between 31 and 40 years, and 13 (31.7%) were between 41 and 50 years. There were 24 males (58.5%) and 17 females (41.5%). Regarding sagittal skeletal patterns, 20 (48.8%) were Class-I, 10 (24.4%) were Class-II, and 11 (26.8%) were Class-III. For vertical skeletal patterns, 28 (68.3%) were normodivergent, 8 (19.5%) were hypodivergent, and 5 (12.2%) were hyperdivergent. The mesiobuccal root distance to the MSF was Type-1 in 29 cases (70.7%), Type-2 in 12 (29.3%), and Type-3 in none. The distobuccal root distance to the MSF was Type-1 in 26 cases (63.4%), Type-2 in 15 (36.6%), and Type-3 in none. The palatal root distance to the MSF was Type-1 in 23 participants (56.1%), Type-2 in 11 (26.8%), and Type-3 in 7 (17.1%). Education levels showed that 6 participants (14.6%) had primary education, 7 (17.1%) had middle-level education, 4 (9.8%) had high school education, 7 (17.1%) had college education, 10 (24.4%) had university education, and 7 (17.1%) were uneducated.

Table 2: Frequencies and Percentages of Qualitative Variables

Qualitative Variables		Frequency	Percentage
Age Groups	18-30	17	41.5%
	31-40	11	26.8%
	41-50	13	31.7%
Gender	Male	24	58.5%
	Female	17	41.5%
Sagittal Skeletal Patterns	Class-I	20	48.8%
	Class-II	10	24.4%
	Class-III	11	26.8%
Vertical Skeletal Pattern	Normodivergent	28	68.3%
	Hypodivergent	08	19.5%
	Hyperdivergent	05	12.2%
Mesiobuccal Root Distance to MSF	Type 1	29	70.7%
	Type 2	12	29.3%
	Type 3	0	0%
Distobuccal Root Distance to MSF	Type 1	26	63.4%
	Type 2	15	36.6%
	Type 3	0	0%
Palatal Root Distance to MSF	Type 1	23	56.1%
	Type 2	11	26.8%
	Type 3	07	17.1%
Education Level of Patients	Primary	06	14.6%
	Middle	07	17.1%
	High	04	09.8%
	College	07	17.1%
	University	10	24.4%
	Uneducated	07	17.1%

Table 3 shows the Spearman's correlation between root apex distances to the MSF and skeletal patterns. For the mesiobuccal root, the correlation with the ANB angle was weak and positive (r = 0.182), but it was not statistically significant (p = 0.127). Its correlation with SN-MP was almost zero (r = 0.012) and also not significant (p = 0.472). For the distobuccal root, the correlation with ANB was weak and negative (r = -0.138), with a non-significant p-value of 0.388. The correlation with SN-MP was nearly zero (r = 0.010), and the p-value (0.948) confirmed no significant relationship. For the palatal root, the correlation with ANB was also weak and negative (r = -0.085), with a p-value of 0.596, indicating no significant association. The correlation with SN-MP was moderate and negative (r = -0.252), but again, it was not statistically significant (p = 0.111). In summary, none of the correlations between root apex distances to the MSF and skeletal patterns were statistically significant, suggesting that these distances did not depend on sagittal or vertical skeletal types in this sample.

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Table 4 shows stratification of the distance between the mesiobuccal root apex and the MSF by age, gender, and education level. In the 18-30 age group, 14 participants (34.1%) had Type-1 diabetes, 3 (7.3%) had Type-2 diabetes, and none had Type-3 diabetes. In the 31-40 age group, 7 (17.1%) had Type-1 and 4 (9.8%) had Type-2. In the 41–50 group, 8 (19.5%) had Type-1 and 5 (12.2%) had Type-2. Among males, 17 (41.5%) had Type-1 and 7 (17.1%) had Type-2. Among females, 12 (29.3%) had Type-1 and 5 (12.2%) had Type-2. Among education levels, 5 (12.2%) with primary education had Type-1 and 1 (2.4%) had Type-2; 5 (12.2%) with middle education had Type-1 and 2 (4.9%) had Type-2; 2 (4.9%) with high education had Type-1 and 2 (4.9%) had Type-2; 7 (17.1%) with college education had Type-1 and none had Type-2; 8 (19.5%) with university education had Type-1 and 2 (4.9%) had Type-2; 2 (4.9%) uneducated participants had Type-1 and 5 (12.2%) had Type-2.

Table 3: Spearman's Correlation between the Distances from the Root Apices to the MSF in Both Sagittal and Vertical Skeletal Patterns for each Root

Root Apex Distance	Skeletal Pattern	Spearman's P (Correlation Coefficient)	P-Value
Mesiobuccal	ANB (Sagittal)	0.182	0.127
	SN-MP (Vertical)	0.012	0.472
Distobuccal	ANB (Sagittal)	-0.138	0.388
	SN-MP (Vertical)	0.010	0.948
Palatal	ANB (Sagittal)	-0.085	0.596
	SN-MP (Vertical)	-0.252	0.111

Table 4: Stratifications of the Distance between the Mesiobuccal Root Apex and MSF with respect to Age Groups, Genders, and Education Level

Qualitative Variables		Distance of the Mesiobuccal Root Apex to the MSF						P-Value
		Type 1		Type 2		Type 3		
		F	%	F	%	F	%	
Age Groups	18-30	14	34.1%	03	7.3%	0	0%	0.385
	31-40	07	17.1%	04	9.8%	0	0%	
	41-50	08	19.5%	05	12.2%	0	0%	
Gender	Male	17	41.5%	07	17.1%	0	0%	0.986
	Female	12	29.3%	05	12.2%	0	0%	
Education Level	Primary	05	12.2%	01	2.4%	0	0%	0.060
	Middle	05	12.2%	02	4.9%	0	0%	
	High	02	4.9%	02	4.9%	0	0%	
	College	07	17.1%	0	0.0%	0	0%	
	University	08	19.5%	02	4.9%	0	0%	
	Uneducated	02	4.9%	05	12.2%	0	0%	

Table 5 shows the stratification of the distobuccal root apex distance to the MSF by the same variables. In the 18–30 age group, 14 (34.1%) had Type-1 and 3 (7.3%) had Type-2. In the 31–40 group, 4 (9.8%) had Type-1 and 7 (17.1%) had Type-2. In the 41–50 group, 8 (19.5%) had Type-1 and 5 (12.2%) had Type-2. Among males, 13 (31.7%) had Type-1 and 11 (26.8%) had Type-2. Among females, 13 (31.7%) had Type-1 and 4 (9.8%) had Type-2. For education levels, 4 (9.8%) with primary education had Type-1 and 2 (4.9%) had Type-2; 6 (14.6%) with middle education had Type-1 and 1 (2.4%) had Type-2; 1 (2.4%) with high education had Type-1 and 3 (7.3%) had Type-2; 4 (9.8%) with college education had Type-1 and 3 (7.3%) had Type-2; 7 (17.1%) with university education had Type-1 and 3 (7.3%) had Type-2; 4 (9.8%) uneducated participants had Type-1 and 3 (7.3%) had Type-2.

Table 6 shows the stratification of the palatal root apex distance to the MSF. In the 18–30 age group, 11 (26.8%) had Type-1, 4 (9.8%) had Type-2, and 2 (4.9%) had Type-3. In the 31–40 group, 3 (7.3%) had Type-1, 4 (9.8%) had Type-2, and 4 (9.8%) had Type-3. In the 41–50 group, 9 (22.0%) had Type-1, 3 (7.3%) had Type-2, and 1 (2.4%) had Type-3. Among males, 12 (29.3%) had Type-1, 8 (19.5%) had Type-2, and 4 (9.8%) had Type-3. Among females, 11 (26.8%) had Type-1, 3 (7.3%) had Type-2, and 3 (7.3%) had Type-3. In education levels, 3 (7.3%) with primary education had Type-1, 1 (2.4%) had Type-2, and 2 (4.9%) had Type-3; 5 (12.2%) with middle education had Type-1 and 2 (4.9%) had Type-2; 2 (4.9%) with high education had Type-1 and 2 (4.9%) had Type-3; 4 (9.8%) with college education had Type-1, 2 (4.9%) had Type-2, and 1 (2.4%) had Type-3; 6 (14.6%) with university education had Type-1, 2 (4.9%) had Type-2, and 2 (4.9%) had Type-3; 3 (7.3%) uneducated participants had Type-1, 4 (9.8%) had Type-2, and none had Type-3.

Table 5: Stratifications of the Distance between the Distobuccal Root Apex and MSF with respect to Age Groups, Genders, and Education Level

Qualitative Variables		Distance of the Distobuccal Root Apex to the MSF						P-Value
		Type 1		Type 2		Type 3		
		F	%	F	%	F	%	
Age Groups	18-30	14	34.1%	03	7.3%	0	0.0%	0.047
	31-40	04	9.8%	07	17.1%	0	0.0%	
	41-50	08	19.5%	05	12.2%	0	0.0%	
Gender	Male	13	31.7%	11	26.8%	0	0.0%	0.144
	Female	13	31.7%	04	9.8%	0	0.0%	
	Primary	04	9.8%	02	4.9%	0	0.0%	0.480

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Education Level	Middle	06	14.6%	01	2.4%	0	0.0%	
	High	01	2.4%	03	7.3%	0	0.0%	
	College	04	9.8%	03	7.3%	0	0.0%	
	University	07	17.1%	03	7.3%	0	0.0%	
	Uneducated	04	9.8%	03	7.3%	0	0.0%	

Table 6: Stratifications of the Distance between the Palatal Root Apex and MSF with respect to Age Groups, Genders, and Education Level

Qualitative Variables		Distance of the Palatal Root Apex to the MSF						P-Value
		Type 1		Type 2		Type 3		
		F	%	F	%	F	%	
Age Groups	18-30	11	26.8%	04	9.8%	02	4.9%	0.191
	31-40	03	7.3%	04	9.8%	04	9.8%	
	41-50	09	22.0%	03	7.3%	01	2.4%	
Gender	Male	12	29.3%	08	19.5%	04	9.8%	0.522
	Female	11	26.8%	03	7.3%	03	7.3%	
Education Level	Primary	03	7.3%	01	2.4%	02	4.9%	0.403
	Middle	05	12.2%	02	4.9%	0	0.0%	
	High	02	4.9%	0	0.0%	02	4.9%	
	College	04	9.8%	02	4.9%	01	2.4%	
	University	06	14.6%	02	4.9%	02	4.9%	
	Uneducated	03	7.3%	04	9.8%	0	0.0%	

DISCUSSION

The present study evaluated the relationship between maxillary first molar root apices and the maxillary sinus floor (MSF) across different skeletal patterns. It demonstrated no statistically significant correlations between sagittal/vertical skeletal classifications (ANB angle, SN-MP angle) and root-MSF distances. These findings contrast with previous studies that reported skeletal pattern influences. For instance, Costea et al. found low-angle skeletal groups had significantly greater root-MSF distances compared to high-angle groups (10). In comparison, Ahn and Park observed shorter distances in Class II anteroposterior relationships compared to Class III (11). This discrepancy may stem from differences in sample demographics, as our study focused on adults (mean age 34.46 years) compared to broader age ranges (10-28 years) and (7-24 years) in prior research (10, 11).

Notably, our results align with spiral CT findings from Iraq, which showed no significant side or gender differences in root-MSF relationships (12). Both studies identified the mesiobuccal root of the 1st molar as the closest to the MSF. However, our measurements (3.33 ± 1.69 mm for mesiobuccal roots) were greater than those reported in another study conducted on Pakistani populations (1.41-2.85 mm) (4). This variation could reflect ethnic differences in sinus pneumatization patterns or measurement methodology variations between CBCT and conventional CT (13).

In the present study, age emerged as a critical factor, with younger participants (18-30 years and 31-40 years age groups) showing shorter root-MSF distances and higher rates of root protrusion (Type-2 and Type-3), consistent with CBCT studies demonstrating increased sinus pneumatization with aging (13, 14). Specifically, 41-50-year-olds exhibited 19.5% Type-1 relationships for mesiobuccal roots compared to 34.1% in younger cohorts1, supporting the concept of progressive sinus expansion reducing root proximity (14).

The lack of gender differences in root-MSF relationships supports findings from multiple CBCT studies (12, 13, 1), though some reports suggest sexual dimorphism in sinus dimensions. This study stratified the distances of root apices to the MSF by education level, revealing no significant correlations —a novel finding not previously addressed in the literature.

The limitations of this study include the single-center design and moderate sample size (n=41). Multicenter studies with 3D volumetric analyses could better characterize the dynamic interplay between craniofacial growth patterns and sinus anatomy. Nevertheless, these findings enhance preoperative risk assessment for procedures involving the posterior maxilla, particularly in younger patients, where root protrusion risks are elevated.

CONCLUSION

This study found no significant correlation between maxillary first molar roots, MSF distances, and sagittal or vertical skeletal patterns, differing from previous studies that reported such associations. The mesiobuccal root was closest to the MSF, and younger age groups showed shorter distances and more root protrusion, suggesting increased sinus pneumatization with age. No significant differences were observed based on gender or education level. Despite a limited sample size, the findings highlight the importance of age-related anatomical variation in preoperative planning for posterior maxillary procedures.

DECLARATIONS

Data Availability Statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department Concerned. (IRB)

Consent for publication

Approved

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

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