

Assessing the Divergence of Maxillary Molar Roots and Maxillary Sinus Floor Position in North Maharashtra population: An Observational CBCT based Study

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ABSTRACT:

Objective: To evaluate the relationship between maxillary molar root divergence and the position of the maxillary sinus floor in the North Maharashtra population using cone-beam computed tomography (CBCT). **Study design:** 34 CBCT scans of patients aged 20–60 years were analyzed. The vertical relationship between maxillary molar roots and the sinus floor was classified using Kwak's classification (Types I–V). Root divergence angles (mesiobuccal-distobuccal, mesiobuccal-palatal, and distobuccal-palatal) were measured. Statistical analysis was performed using the Chi-square test and Pearson's correlation coefficient. **Results:** The most common sinus floor positions were Type IV (26.5%, palatal root protrusion) and Type V (23.5%, both buccal and palatal root protrusion). A significant association was found between root divergence and sinus floor type ($\chi^2 = 12.094$, $*p = 0.028$). A weak negative correlation (Pearson's $*r = -0.359$, $*p = 0.037$) suggested that greater root divergence was associated with specific sinus floor configurations. **Conclusion:** The study highlights the high prevalence of maxillary molar root protrusion into the sinus, emphasizing the need for CBCT-based assessment in treatment planning for dental implants, extractions, and sinus augmentation procedures to minimize complications.

Keywords: Maxillary sinus floor, maxillary molar roots, root divergence angle, sinus proximity, Cone-beam computed tomography (CBCT), Kwak's classification

INTRODUCTION:

The maxillary sinus (MS) is the largest of the paranasal sinuses and is located within the body of the maxilla, and is pyramidally shaped with its apex towards the zygomatic process of maxilla and base formed by lateral nasal wall.¹ It is involved in reducing skull weight, humidification of the air, and enhancing voice resonance. Clinically, its close proximity to the roots of the maxillary molars makes it a significant structure in dentistry and maxillofacial surgery. The floor of the maxillary sinus runs in close approximation (sometimes overlap) with the apices of the maxillary molars, with which they are separated only by a thin bone septum or Schneiderian membrane.² This close anatomical relationship forms the basis of the clinical significance of the sinus and its floor in dental and maxillofacial practice, as variations in floor position, septation, and membrane thickness can greatly affect the outcomes of procedures such as tooth extraction, implant placement, sinus floor elevation, and the management of odontogenic sinusitis.³ Hence, accurate

imaging and assessment of the sinus anatomy are essential in dental treatment planning.

Maxillary molar root divergence is the angle formed by the separation of two roots of mesiobuccal, distobuccal and palatal root of maxillary molar which is an important clinical implication. It is shown that divergence varies widely, with mean distobuccal palatal angles reaching approximately 45°, and that variability is positively correlated with the proximity to the maxillary sinus floor. Anatomical surveys also reveal frequent occurrences of root fusion and accessory canals, such as a second canal in the mesiobuccal root (>70% in some populations).⁴ These morphological variations can complicate the results in navigation system and surgical access or increase the risk of sinus perforation and the survival of the implant.

Three-dimensional imaging especially cone-beam computed tomography (CBCT) has emerged as a superior imaging modality for evaluating these complex anatomical relationships. These images

provide 3D view with high precision, which could overcome the limitation of conventional 2D radiograph, such as periapical and panoramic radiograph.⁵ CBCT provides accurate assessments of root morphology, the angle and direction of root divergence in maxillary molars and its relationship to the maxillary sinus floor.⁶ This is particularly important in treatment planning for procedures such as extractions, dental implant placement, sinus elevation, and endodontic surgeries.⁷ CBCT can help identify anatomical variations, thin sinus floors, or root protrusions into the sinus that are difficult to identify using PA or panoramic radiographs.⁸ Therefore, it is used to reduce possible complications of the surgery, perforation of the sinus membrane, and oroantral communication, and to enhance the outcome of the patients.^{5,7}

MATERIALS AND METHODS:

This study was conducted in the department of Oral Medicine and Radiology, MGVs KBH Dental College, Nashik after obtaining the approval from institutional ethical committee and acceptance from Maharashtra University of Health Sciences. 34 CBCT scans of patients aged between 20 and 60 years was selected from the data available on the CBCT unit server. The study was carried out between April 2024 and July 2024. The scans selected were of patients such as those referred for diagnostic assessments of the maxillary arch. The scans specifically included the maxillary first and second molars.

The inclusion criteria comprised high quality CBCT scans of fully matured maxillary molars showing wall of maxillary sinus floor.

The exclusion criteria excluded the scans with intra radicular fillings or any types of fixed prosthesis, scans of maxillary molars with radiographic evidence of pathology (dental caries, pulp stones, tooth fractures, etc.), scans with bony pathology in region of interest (cyst, tumor, malignancy, developmental defects inflammatory, infectious disease, periodontal pathology, etc.), scans with supernumerary teeth, and scans showing radiographic evidence of trauma and

surgical procedure, scans showing radiographic artifacts, partial image in the region of interest, scans showing fused roots and severely curved non marked roots. The total number of roots in the maxillary first and second molar in each scan was observed. The canal morphology was examined in all three views (axial, coronal, sagittal) to ensure reliability.

The vertical relationship between the root apices of the maxillary molars and the floor of the maxillary sinus were classified according to a system proposed by Kwak et al. (2004)⁹. This system categorizes the anatomical proximity and interaction of the sinus floor with the buccal and palatal root apices into 5 types-

In Type I, the inferior wall of the maxillary sinus lies entirely above the apices of both buccal and palatal roots.

Type II, the sinus floor is exactly at the level of the root apices; however, there is no protrusion of the roots into the sinus cavity.

Type III, the apical protrusion of the buccal root apex beyond the sinus floor.

Type IV, the protrusion of palatal root apex into the sinus cavity.

Type V, both the buccal and palatal root apices protrude over the inferior wall of the sinus.

The divergence angle was assessed by measuring the angle formed between the roots, specifically between the mesiobuccal (MB) and distobuccal (DB) roots, MB and palatal roots, and DB and palatal roots.

To measure the divergence angle, a horizontal reference line was drawn at the level of the pulpal floor of the maxillary first or second molars. This line served as a baseline from which measurements are taken.

Lines were also drawn between the pulpal floor and the mesiobuccal root apex and between the pulpal floor and the distobuccal (or palatal for any root comparison).

The angle formed at the intersection of these lines represented the divergence angle and was calculated accordingly.

Figure 1: Vertical Relationship of The Maxillary Root Apices with The MSF According to Kwak's Classification⁹

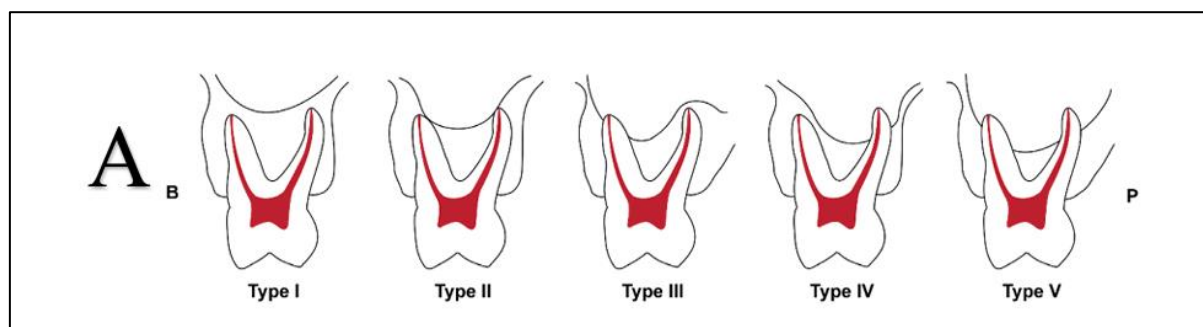


Figure 2: The measurement of the divergence angle between the roots⁹

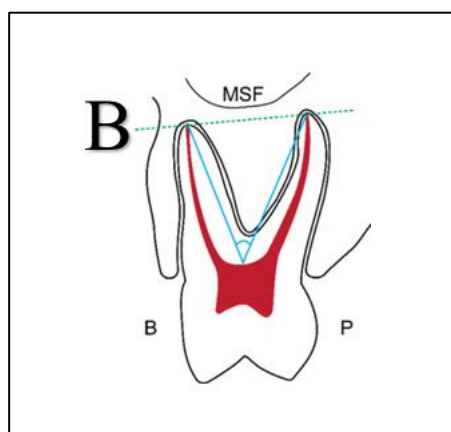


Figure 3: Cone beam computed tomography of permanent maxillary first molar showing measurement of divergence angle between the roots



Statistical Analysis:

Statistical analysis was performed using Statistical package for social sciences (SPSS) software (IBM Corp) (v.21.0). Chi-square test of association was performed to assess the association between the types of position of the wall with the divergence angle. Pearson's correlation coefficient test was used to assess significant difference between the different types of position of the wall with the divergence angle. A p value of less than 0.05 was considered as statistically significant at 95% confidence intervals in the study.

RESULTS:

Position of Maxillary Sinus Floor according to the Kwak Classification:

The distribution of the maxillary sinus floor position among the study participants, classified according to the Kwak classification, is mentioned in Table 1. Among the 34 cases analyzed, Type IV was the most frequently observed pattern, accounting for 26.5% (n = 9) of the total sample, followed closely by Type V at 23.5% (n = 8). Type III was identified in 20.6% (n = 7) of participants, while Types I and II were each observed in 14.7% (n = 5) of the cases. These findings indicate a higher prevalence of sinus floor types positioned closer to or overlapping with the root apices (Types III–V), which may have clinical implications in endodontic and surgical planning involving the posterior maxilla.

Table 1: Prevalence Based on The Position of The Maxillary Sinus Floor Wall

Type	Frequency(n)	Percentage (%)
Type I	5	14.7
Type II	5	14.7
Type III	7	20.6
Type IV	9	26.5
Type V	8	23.5
Total	34	100.0

Association between the different types of position of the wall of maxillary sinus floor:

Table 2 shows the association between the different types of maxillary sinus floor positions, as classified by the Kwak system, and the divergence angle of the maxillary molar roots. The angles were grouped into three categories <21°, 21–45°, and >45°. The analysis was performed using the Chi-square test, and a statistically significant association was found ($\chi^2 = 12.094$, $p = 0.028$). This suggests that the pattern of

sinus floor position may be related to the divergence angle of the molar roots. For example, Type I and IV configurations were more frequently associated with moderate divergence angles (21–45°), while Type II showed a higher frequency of wide divergence angles (>45°). These results imply that variations in root divergence may influence or reflect the spatial relationship between the sinus floor and molar roots, which could be important for clinical planning in procedures involving the posterior maxilla.

Table 2: Prevalence of the number of root canals in permanent mandibular first molars:

Type	Divergence Angle			Total	Chi-square value	p value
	< 21 degrees	21-45 degree	> 45 degrees			
Type I	0	4	1	5	12.094	0.028*
Type II	1	1	3	5		
Type III	2	4	1	7		
Type IV	3	6	0	9		
Type V	4	3	1	8		
Total	10	18	6	34		

*p value <0.05 statistically significant, <0.01 highly significant

Correlation between the different types of position of the wall of maxillary sinus:

Pearson Correlation Coefficient (-0.359*) shows the negative value (-0.359) which indicates a weak to moderate inverse (negative) correlation between root divergence angle and sinus floor type. This means that as root divergence increases, there is a tendency for the

sinus floor type to shift toward certain configurations (or vice versa). p-value (0.037*) is less than the typical alpha threshold of 0.05, meaning the observed correlation is statistically significant. This suggests that the relationship between root divergence and sinus floor type is unlikely due to random chance.

Table 3: Correlation between the different types of position of the wall of maxillary sinus floor according to Kwak classification.

Angle*type		Type
Angle	Pearson Correlation	-.359*
	p value	.037*
	N	34

*p value <0.05 statistically significant, <0.01 highly significant

DISCUSSION:

The present study evaluated the relationship between maxillary molar roots and the maxillary sinus floor using CBCT imaging, focusing on root divergence angles and their association with sinus floor position according to Kwak's classification. The findings contribute to the growing understanding of this clinically significant anatomical relationship, which has important implications for dental extractions, implant placement, sinus augmentation, and endodontic procedures. The results demonstrated that Type IV (26.5%) and Type V (23.5%) were the most common configurations, where either the palatal root or both buccal and palatal roots protruded into the sinus cavity. This aligns with previous studies by Kwak et al. (2004)⁹ and Sharan & Madjar (2006)¹⁰, who reported that root protrusion into the sinus was a

frequent anatomical variation, particularly for maxillary first molars. In contrast, Type I (14.7%) and Type II (14.7%), where the sinus floor lies above or at the level of the root apices without protrusion, were less common, suggesting that most patients have roots in close association with the sinus, necessitating careful preoperative assessment to avoid iatrogenic complications.

A key finding was the statistically significant association between root divergence angle and sinus floor position, with Type I and IV more frequently associated with moderate divergence angles (21–45°), while Type II showed a higher prevalence of wide divergence angles (>45°). These findings are consistent with studies by Jung & Cho (2015)¹¹, who observed that increased root divergence correlated with sinus proximity and higher perforation risks during implant placement.

The negative Pearson correlation further suggested that roots with less divergence may be more likely to protrude into the sinus, possibly due to reduced interradicular space. Clinically, these findings illustrate the continued value of CBCT in treatment planning, particularly for extractions and implant placement in Type III–V cases, where root protrusion increases sinus perforation risk. Previous studies by Razumova et al. (2019)¹² and Thembekumkwun S. et al. (2019)¹³ support this, showing that CBCT reduces complications compared to 2D radiography and helps manage challenges related to root morphology. Additionally, the presence of Type IV and V configurations may complicate endodontic treatment due to root curvature and accessory canals, as noted by Herrero-Hernández S. et al.¹⁴, highlighting the value of CBCT in identifying such variations.

Our study differs from previous studies and complements the literature of Kwak et al.'s⁹ results by clearly showing the direct association between root divergence and the position of the sinus floor and thereby doing better than Jung & Cho's⁶ panoramic measurements with a more precise CBCT. Although Sharan & Madjar¹⁰ focused on sinus pneumatization, our results combine both parameters for a more comprehensive anatomical assessment.

This study confirms that maxillary molar root divergence angles are significantly associated with maxillary sinus floor position, with Type IV and V configurations being most prevalent. These findings underscore the importance of CBCT in treatment planning to minimize risks of sinus perforation and implant failure. Future studies with larger samples could further validate these associations and refine clinical guidelines for managing this critical anatomical relationship.

CONCLUSION:

The present study highlights a significant association between the roots of the maxillary molars and the maxillary sinus, with findings showing that in many cases, the roots either contact or protrude into the sinus. The most common patterns observed were Type IV (26.5%), where the palatal root protrudes into the sinus, and Type V (23.5%), where both buccal and palatal roots enter the sinus cavity. Additionally, we found a significant connection between root divergence angles and sinus position—teeth with moderate root divergence (21–45°) were frequently seen in Type I and IV cases, while wider root angles (>45°) were more common in Type II. These results have important clinical implications. Since a large number of patients have molar roots in close proximity to the sinus, dentists and surgeons should use CBCT scans for precise assessment before procedures like extractions, implants, or sinus lifts. This 3D imaging helps avoid complications such as sinus perforation, infections, or implant failures. By understanding these anatomical variations beforehand, clinicians can plan

safer, more effective treatments. In summary, CBCT evaluation of the sinus-tooth relationship is essential for minimizing risks and improving outcomes in dental procedures involving the maxillary molars.

Conflict of Interest:

There are no conflicts of interest.

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