ORIGINAL ARTICLE

Anatomic Relationship between Maxillary Sinus and Maxillary Molars Based on CBCT assessment: A Retrospective Study.

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ABSTRACT

Background
Maxillary molars and the maxillary sinus share close anatomical relationship, which is significant in various dental procedures including tooth extractions, sinus lift surgeries and implant placement. Variations in this relationship can impact clinical outcomes and the risk of complications. Cone Beam Computed Tomography has become a valuable imaging tool for evaluating these structures with high precision.

Objective:
The primary aim of this study was to evaluate proximity between maxillary molars and maxillary sinus using CBCT imaging, with a focus on the closeness of roots of the maxillary molars to the sinus floor and its clinical implications.

Method:
A retrospective study was conducted with 200 patients (104 males, 96 females) who underwent CBCT scans. The proximity between apex of maxillary molars and the MSF was assessed based on the distance of the root apex to the MSF, the cortical and mucosal thicknesses of the MSF, and the classification of the relationship into five types (Type I to V). Statistical analysis was conducted utilizing SPSS version 22.0.

Results:
The shortest distance between root apex andiMSF was 1.56 ± 3.32 mm for the MB root of the left second molar, and 1.61i±i3.37 mm for the right second molar. Cortical bone thickness ranged from 0.44 ± 0.27 mm at the MB root of the right second molar to 0.53 ± 0.45 mm at the palatal root apex of the left first molar. Mucosal thickness rangedifrom 1.51 ± 0.83 mm at the DB root of the right second molar to 1.97 ± 1.04 mm at the distobuccal root apex of the left first molar. Type I relationships were most prevalent (52.5–62.0%), while Type IV and Type V relationships were less common (1.5–6.0%). No significant differences were found based on gender or anatomical location. MB- Mesiobuccal DB- Distobuccal.

Conclusion:
This study investigated the anatomical relationship between the maxillary molar roots and the MSF. Comprehending the distance between root apices and the MSF, together with the thickness of adjacent tissues, is essential for averting difficulties during dental treatments

KEYWORDS: Maxillary sinus, maxillary molars, maxillary sinus floor, CBCT, oroantral fistulas, sinus pneumatization, dental surgery

INTRODUCTION

Maxillary sinus (MS) is a significant anatomical landmark situated adjacent to the apices of the maxillary posterior teeth. It serves a crucial function in dental interventions and other clinical disorders.Around the age of 20, maxillary sinus floor (MSF) is fully developed, which is situated nearly 5 mm below the nasal cavity floor (1,2). The Schneiderian membrane, which lines the inferior wall of he maxillary sinus, serves as a protective barrier but is also susceptible to damage in cases of sinus- related disorders (2).

Several factors, including age, anatomical variations, and local physiological changes, influence the dynamic process of MS development. Research indicates that the level of pneumatization in MS varies widely among individuals. Pneumatization refers to the

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process by which the sinus expands, and this process peaks around the age of 12, after which it reaches its lowest point at around 20 years of age, coinciding with third molars eruption (3,4). Studies have demonstrated that metabolic changes and other factors like tooth extraction, particularly when posterior teeth are involved, can influence the pneumatization of MS (5).

In dental practice, one of the most common surgical procedures involves the extraction of the upper

posterior teeth, particularly molars. However, complications may arise due to the close proximity of the roots of these teeth to the maxillary sinus. Extracting these teeth, especially those with apices that extend close to the sinus floor, increases the risk of creating oroantral fistulas (OAFs), abnormal communications between the oral cavity and the maxillary sinus (6,7). Also, when the sinus flora interacts with the roots of the back molars, it can cause nodules, sinus infections, and roots to accidentally enter the sinus cavity, all of which make treatment more difficult (8).

The correlation between the floor of the sinus and the posterior maxillary ridge (PMR) is integral in understanding the potential risks associated with dental treatments. As the maxillary sinus undergoes pneumatization, its floor extends into the alveolar bone, especially in areas where the teeth are erupting(9). This expansion can lead to the formation of crypts or cavities in the alveolar bone, which may complicate procedures such as tooth extractions, root canal treatments, and dental implant insertions. Pei et al. (2020) discovered that in approximately 50% of patients, the MSF expands across adjacent teeth, sometimes reaching the alveolar bone itself. This can result in a considerable reduction in the height of the posterior alveolar ridge, further complicating dental surgeries (10).

The phenomenon of sinus pneumatization is especially pronounced when examining the eruption of the posterior teeth, starting with the first premolar and continuing through to the third molar. As these teeth emerge, the MSF progressively moves occlusally, enveloping the roots of posterior teeth. Over time, the relationship between the posterior maxillary ridge and the maxillary sinus floor becomes more pronounced, with the height of the alveolar ridge decreasing as part of the natural aging process (11,12).

Moreover, the interaction between the MSF and PMR plays a critical role in preventing complications during dental procedures. For example, if dental implants or invasive root canal treatments are not placed correctly, the roots may move into the sinus, which can cause root displacement or the growth of an oroantral fistula (13,14). Consequently, comprehending the anatomical link between the MSF and PMR is crucial for averting difficulties during dental procedures.

We highly recommend comprehensive preoperative imaging, including CBCT, to mitigate the risks associated with these procedures. This enables a thorough evaluation of the maxillary sinus's position, size, and proximity to the roots of posterior teeth, especially when the sinus exhibits significant pneumatization. Also, keeping a thorough knowledge of how the MSF and PMR work together can help

doctors come up with the best surgical methods, like sinus lifts or bone grafting, to protect the maxillary sinus from damage during tooth extractions or implant placement. The anatomical relationship between MS and the posterior teeth is a crucial consideration in dental treatments. Knowing a lot about the process of sinus pneumatization and how the posterior maxillary ridge changes with age can help dentists spot problems like oroantral fistulas or root displacements before they happen. Future studies should focus on improving surgical techniques and preventivemeasures to minimize these risks and enhance patient outcomes in maxillary sinus-related dental procedures.

AIMS

Before planning any treatment, it is essential to ascertain the angle between the apex of posterior and the MSF in order to prevent complications during the surgery. Aim of the study is to use CBCT to measure distance between the maxillary posterior root apex and the MSF, as well as to evaluate how close the two are to each other.

MATERIALS AND METHOD

Study design

This is a retrospective observational study of CBCT images

Setting

Study will be conducted in Riyadh Elm University Hospital, Riyadh, Saudi Arabia starting from October 20 th to November 20 th . CBCT data was be collected from Riyadh Elm university Hospital patient database.

Participants

CBCT from year 2020 until 2024 was retrieved and identified. Random number generator was be use to select images randomly.

Criteria

Inclusion criteria

1. Patients aged 20 to 40 who have fully developed maxillary roots from the first molar to the third molar and have fully erupted maxillary teeth.
2. High-resolution CBCT radiographs that are precise and free of distortion that are diagnostically competent.
3. The radiographic images must not contain any radiolucent or radiopaque lesions in the mandibular molar region.
4. Teeth that are well-aligned in the studied area and do not exhibit malocclusion.

Criteria for Exclusion

1. The study area is characterized by the absence of dentition.
2. The images are not lucid.
3. Images in the study area that contain anomalies, distortion, and superimposed metal objects.
4. Incomplete eruption of teeth or mixed dentition
5. Orthodontic treatment history.

Sample Size

Sample size was calculated employing Cochrane's formula, utilizing a confidence interval of 95% and a 5% error for margin. The sample size therefore is 200.

Formula used for the calculations was:

$$n = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P * (1-P))}$$

Where :

n = sample size

X^2 = Chi – square for the specified confidence level at 1 degree of freedom

N = Population Size

P = population proportion (.50 in this table)

ME = desired Margin of Error (expressed as a proportion)

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MEASUREMENTS

CBCT images were acquired using Sidexis software. The measurement sections were chosen when the root tip was visible in the coronal or sagittal plane. The measurements encompassed the distance from the root apices of the maxillary molars to the MSF, the thickness of the mucosa and cortical bone at the root apices of the MSF the specific measurements encompassed the distance from the mesiobuccal root apex to the inferior wall of the MSF (DMBR), the distance from the distobuccal root apex to the inferior wall of the MSF (DDBR), the distance from the palatal root apex to the inferior wall of the MSF (DPR), the cortical thickness of the MSF nearest to the mesiobuccal root apex (CTMBR), the cortical thickness of the MSF nearest to the distobuccal root apex (CTDBR), the cortical thickness of the MSF nearest to the palatal root apex (CTPR), the mucosal thickness of the MSF nearest to the mesiobuccal root apex (MTMBR), the mucosal thickness of the MSF nearest to the distobuccal root apex (MTDBR), and the mucosal thickness of the MSF nearest to the palatal root apex (MTPR) (Figure 1).
CBCT cross-sectional images were utilized to assess the vertical relationships between the root apices of the maxillary molars and the MSF, categorizing these relationships into five types (Type 1–5) based on the criteria established by Kwak et al. (2017).

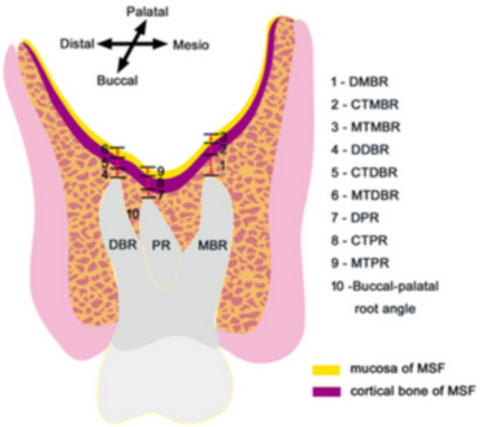


Figure 1- Measurements of maxillary molars using CBCT cross sectional images

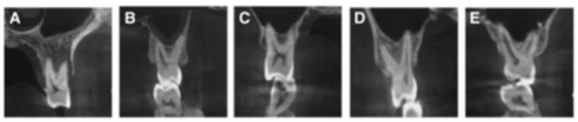


Figure 2- CBCT cross-sectional images were utilized to assess the vertical relationships between the root apices of the maxillary molars and the MSF categorizing these relationships into five types (Type 1-5) based on the criteria established by Kwak et al (2017).
Type I Maxillary Sinus Floor is just above the point where buccal and palatal root apices meet.
Type II: MSF is below the junction of the buccal and palatal root apices.
(Above MSF without any protrusions)
Type III: The buccal root apex displays an apical protrusion over the Maxillary Sinus Floor.
Type IV: At the tip of the palatal root, there is an apical projection that meets the MSF..
Type V: Apical protrusions at the apices of the buccal and palatal roots are made over the Maxillary Sinus Floor.

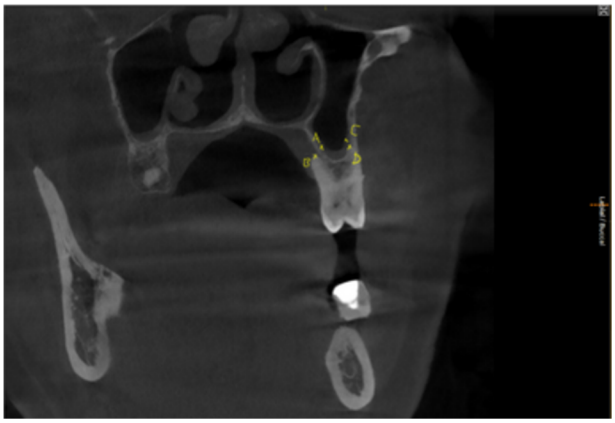


Figure 3- Landmarks for measurements
Point A and C- denotes Inferior wall of maxillary sinus floor
Point B- denotes apex of palatal root of maxillary 2nd molar
Point D- denotes Mesiobuccal root of maxillary 2nd molar

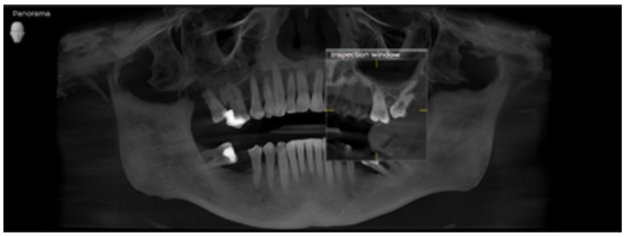


Figure 4- Close up image of a random CBCT

Stattistical analysis

Statistical analysis was done with SPSS version 22.0. Unpaired t-test were employed to assess differences between men and women, while pairedit-tests wereiutilized to evaluate differences between left and right sites. In all studies, a p-value of less than 0.05 was considered statistically significant.

Ethical consideration

Ethical clearance was obtained from the research center of Riyadh elm University with registration number FUGRP /2024/380/1187 and IRB number FUGRP /2024/380/1187/1052 80/1187/1052

RESULTS

Comparison of the relationship between the maxillary molars and the MSF based on gender and location

In a sample size of 104 males and 96 females, we studied the effects of gender and location of the an atomical link between the maxillary molars and maxillary sinuses. We found no significant differences based on gender or location for variables such as the rate of maxillary sinus penetration, distance from the apex of the maxillary molar root to the maxillary sinus floor (MSF), mucosal thickness of the MSF, cortical bone thickness of the MSF, prevalence of different relationship types (Typei1-5) between the molar roots and the MSF.

Distance between root apex of the maxillary molars and maxillary sinus floor

Aicomparison of the distance between the root apices of the maxillary molars and the floor of the maxillary sinus was conducted. The minimum distance from the tip ofitheiroot to theimaxillaryisinusifloor was 1.56 ± 3.32 mm for the mesiobuccal root of the left second molar and 1.61i± 3.37 mm for the mesiobuccal root of the right second molari[Table 1].

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Tooth	n	MB-MSF	DB-MSF	PR-MSF
Max Rt 1st Molar	200	2.07 ± 3.35	2.32 ± 3.19	2.58 ± 3.47
Max Rt 2nd Molar	200	1.61 ± 3.37	1.85 ± 3.32	2.87 ± 3.12
Max Lft 1st Molar	200	2.26 ± 3.28	2.41 ± 3.41	2.28 ± 3.18
Max Lft 2nd Molar	200	1.56 ± 3.32	1.88 ± 3.15	2.51 ± 3.07

Table 1- Distance between apex of maxillary molar roots and the maxillary sinus floor

MB-MSF-Distance between mesiobuccal root and the inferior wall of the MSF; DB-MSF- Distance between distobuccal root and the inferior wall of the MSF; PR- Distance between palatal root and the inferior wall of the maxillary sinus floor.

Corticaliboneiand mucosaithickness of maxillary sinus floor closestito theiroot apices

The thickness of cortical bone and mucosa of maxillary sinus floor adjacent to mesiobuccal, distobuccal, and palatal root apex was assessed and compared. The findings indicated that the cortical bone of the maxillary sinus floor exhibited the minimum thickness at the mesiobuccal root apex of the right second molar(0.44 ± 0.27 mm) and the maximum thickness at the palatal root apex of the left first molari(0.53 ± 0.45 mm) [Table 2].

Tooth	n	CTMBR	CTDBR	CTPR
Max Rt 1st Molar	200	0.51 ± 0.33	0.47 ± 0.28	0.49 ± 0.30
Max Rt 2nd Molar	200	0.44 ± 0.27	0.46 ± 0.33	0.49 ± 0.47
Max Lft 1st Molar	200	0.50 ± 0.47	0.51 ± 0.42	0.53 ± 0.45
Max Lft 2nd Molar	200	0.48 ± 0.28	0.49 ± 0.62	0.46 ± 0.36

Table 2- Cortical thickness of the maxillary sinus floor at the maxillary molars root apices

CT-BR Cortical thickness of maxillary sinus floor at the mesiobuccal root apex; CT-DR, cortical thickness of the maxillary sinus floor at the distobuccal root apex; CT-PR, cortical thickness of the MSF at the palatal root apex.

The MSF mucosa was thinnest at the distobuccal root of right second molar (1.51 ± 0.83 mm) and thickest at the distobuccal root apex of the left first molar (1.97 ± 1.04 mm) [Table 3].

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Tooth	n	Mucosal thickness at MB root apex	Mucosal thickness at DB root apex	Mucosal thickness at palatal root apex
Max Rt 1st Molar	200	1.76 ± 0.85	1.82 ± 1.02	1.82 ± 1.16
Max Rt 2nd Molar	200	1.65 ± 1.02	1.51 ± 0.83	1.72 ± 0.63
Max Lft 1st Molar	200	1.93 ± 0.97	1.97 ± 1.04	1.91 ± 1.11
Max Lft 2nd Molar	200	1.76 ± 0.71	1.70 ± 1.04	1.76 ± 1.18

Table 3- The mucosal thickness of the MSF at the root apices of the maxillary molars

MB-mesiobuccal root; DB- distobuccal root apex; PR-palatal root.
Table 4 illustrates the rates of the various categories of relationships (Type 1–5) between the maxillary molar roots and the MSF. According to the findings, Type I relationships were predominantly identified in all maxillary molars (52.5–62.0%), while Type IV relationships were least frequently noted in the right second molar (1.5%), left first molar(6.0%), and left second molar (2.0%). Type V relationships were also rarely observed in the right second molar (3.5%) [Table 4].

Tooth	n	TYPE I	TYPE II	TYPE III	TYPE IV	TYPE V
Max Rt 1st Molar	200	105 (52.5%)	47 (23.5%)	18 (9%)	17 (8.5%)	13 (6.5%)
Max Rt 2nd Molar	200	120 (60%)	43 (21.5%)	27 (13.5%)	3 (1.5%)	7 (3.5%)
Max Lft 1st Molar	200	108 (54%)	56 (28%)	12 (6%)	12 (6%)	15 (7.5%)
Max Lft 2nd Molar	200	124 (62%)	28 (14%)	32 (16%)	4 (2%)	10 (5%)
Total	800	457 (57.125%)	174 (21.75%)	89 (11.13%)	36 (4.5%)	45 (5.6%)

Table 4 Types of relationships between the maxillary molar roots and the maxillary sinus floor

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DISCUSSION

The current study looked at the connection between the maxillary molars and the maxillary sinus floor (MSF). It did this by examining factors such as the distance between the molars' root apex and the MSF, the thicknesses of the MSF's cortex and mucosa, and the number of different types of anatomical relationships. This analysis was conducted on a sample of 104 males and 96 females to determine the impact of gender and anatomical location on these variables. Overall, the study found no significant differences in the anatomical relationships between the maxillary molars and the MSF based on gender or location. These findings align with previous studies, suggesting that these anatomical relationships remain relatively constant across different populations.

Gender and Location-Based Variations

The study didn't find any important differences between men and women in the rate of maxillary sinus penetration, the distance from the root's tip to the MSF, or the thickness of the MSF's mucosa and cortical bone. This is consistent with the findings of other studies, such as those by DeLillo et al. (2017) and Zhang et al. (2019), which reported that gender did not significantly affect the spatial relationships between the maxillary molars and the MSF. These results could be attributed to the fact that the anatomical structures of the maxillary molars and sinuses show little variation between genders, with the overall size of the maxillary sinus being relatively stable regardless of sex.

Similarly, the study did not find significant differences based on location for the variables analyzed. Specifically, the distance from the apex of the root to the MSF did not differ notably between the mesiobuccal, distobuccal, and palatal roots. This lack of significant difference aligns with other research, such as that by Gungor et al. (2015) and Kim et al. (2018), which showed that the roots of the maxillary molars and the MSF are generally connected in the same way across different parts of the upper jaw.

Distance Between Molar Roots and MSF

The results revealed that the shortest distance between the root apices of the maxillary molars and the MSF was approximately 1.56 ± 3.32 mm at the mesiobuccal root of the left second molar and 1.61 ± 3.37 mm at the mesiobuccal root of the right second molar. Previous studies, such as Akarslan et al. (2019), found that the root apex-to-MSF distance varied between 1 and 2 mm in most cases, consistent with these findings. This distance is clinically significant as it helps in assessing potential risks for sinus perforation during dental procedures like molar extractions or implant placement.

Cortical and Mucosal Thickness

The study found that the MSF's cortical bone was thinnest at the mesiobuccal root apex of the right molar (0.44 ± 0.27 mm) and thickest at the palatal root apex of the left first molar (0.53 ± 0.45 mm). The mucosal thickness was thinnest at the distobuccal root of the right second molar (1.51 ± 0.83 mm) and thickest at the distobuccal root apex of the left first molar (1.97 ± 1.04 mm). These findings align with previous research by Yildirim et al. (2021), who found that the thickness of the MSF's cortical bone and mucosa varied slightly depending on the molar root and its proximity to the MSF. The variations in cortical bone thickness observed in this study could have implications for dental surgeries, as areas with thinner cortical bone may be more susceptible to perforation during procedures.

Prevalence of Relationship Types

The study also assessed the prevalence of different relationship types (Type I–V) between the molar roots and the MSF. Type I relationships were the most common, identified in 52.5–62.0% of cases, while Type IV relationships were the least common, appearing in only 1.5–6.0% of cases. This finding aligns with the work of Koc et al. (2017), who found that Type I relationships were the most common, with variations occurring primarily in cases where the maxillary molar roots were in close proximity to the sinus floor. This study, as well as previous studies, rarely observed Type IV and Type V relationships, where there is greater encroachment on the MSF, indicating that such anatomical configurations are less prevalent.

Clinical Implications

The results of this study have significant clinical implications, particularly in dental procedures involving the maxillary molars, such as tooth extractions or implant placement. A greater understanding of the distances between the root apices and the MSF, as well as the thickness of the cortical bone and mucosa, can assist clinicians in avoiding complications like sinus perforation. Clinicians can rely on these standard measurements when planning procedures for both male and female patients, regardless of the specific molar under treatment, as the study found no significant differences in these anatomical relationships based on gender or location.

LIMITATIONS OF THE STUDY

One limitation of the study is the relatively small sample size, particularly in terms of the distribution between males and females, which could affect the generalizability of the findings. We need future studies with larger and more diverse populations to confirm these results and explore potential variations based on age, ethnicity, or other factors. Additionally, further research could investigate the influence of pathological conditions, such as sinusitis or molar infections, on the relationship between the maxillary molars and the MSF.

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