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Assessment of Maxillary Molar Roots' Proximity to the Maxillary Sinus Floor in a Libyan Population Using Cone Beam Computed Tomography

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Abstract

Aim: *This cross-sectional study evaluated the anatomical relationship between maxillary molar roots (MMRs) and the maxillary sinus floor (MSF) in Libyan adults, assessing demographic influences. Methods: CBCT images from 102 patients (408 molars; 1,224 roots) were analyzed. Root-MSG relationships were classified as: Class I (apex below MSF), Class II (apex contacting MSF), and Class III (apex protruding into sinus)* ***Results:*** *Distribution: Class I (42%, n=517), and Class II (37%, n=446), Class III (21%, n=261). Prevalence: Class I: Highest in MB roots of first molars (left: 56.9%; right: 52%), Class II: Dominant in DB roots of second molars (left: 49%; right: 48%), and Class III: Most frequent in MB roots of second molars (left: 32.4%; right: 34.3%). There was Significant associations with younger age and male gender ($p<0.05$).* ***Conclusion:*** *Maxillary second molars' buccal roots demonstrate the closest MSF proximity, with higher intrusion risks in males and younger patients. CBCT assessment is recommended for treatment planning.*

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Introduction

Maxillary sinuses (MS) are the largest cavities within the maxillary bone [1]. They are the first paranasal sinuses to develop and cease their growth around the age of 20 years, following the eruption of the third molars. The sinus grows through a process known as pneumatization. Although pneumatization is a physiological process, it can occasionally pose surgical

hazards, such as oro-antral communication following the extraction of maxillary molars and the risk of foreign body or root tip displacement into the sinus cavity [2].These risks are often caused by protrusions of the apices of maxillary molar roots (MMRs) into the sinus, penetrating the maxillary sinus floor (MSF) and creating elevations in the sinus cavity—commonly referred to as hillocks of the upper molar root apices into the sinus [3]. Considering the volume of sinus and its relation to gender and age, several studies found that; the volumes and dimensions of the maxillary sinuses were larger in males than in females, and the more posterior the maxillary teeth, the more probability for root protruding into the sinus [4-7].

The assessment of the relationship between upper teeth and the maxillary sinus (MS) using two- dimensional (2D) imaging provides limited information for the description of the three- dimensional (3D) structures, which may lead to misinterpretation of the relation between the maxillary molar roots (MMR) and the MS [8-11]. Three-dimensional imaging with cone-beam computed tomography (CBCT) can offer a better visualization and detailed understanding of the anatomy of the MS floor (MSF) in relation to the MMR, helping to reduce distortion and superimposition of related anatomical landmarks concerning gender and age [12,13].

Many studies have investigated the sinus-root relationship in different populations, including Chinese Iranian; Brazilian, Bulgarian, Egyptian Anter et al., 2018), and Saudi Arabian populations [8,14-20]. The aim of this study is to assess the relationship and proximity between the maxillary molar roots (MMR) and the maxillary sinus floor (MSF) in a sample of the Libyan population, classify their relationships, and analyze the influence of age and gender effects using cone-beam computed tomography (CBCT) images.

Material and Methods

Ethical Consent: The study was approved by the Ethical Committee of Dental Research in the Faculty of Dentistry, University of Benghazi, given approval number (0104). Because of the retrospective approach of this project, no informed consent from the patients was obtained.

The Sample: CBCT images of 269 patients were collected from a private dental clinic in Benghazi, Libya, of which 102 files met the inclusion criteria. The sample comprised 204 CBCT images belonging to 102 Libyan patients who had already undergone radiographic imaging during their dental treatment; no patient in the sample was scanned solely for the purpose of this study. The sample included 120 CBCT images from 45 males and 57 females, aged between 20 and 63 years. These images provided a total of 538 views. All patient names and personal data were anonymized and not disclosed in any part of this study. The sample was collected between December 2021 and November 2022, following the inclusion and exclusion criteria outlined below.

Inclusion Criteria: adult Libyan individuals over 20 years old, with fully developed and healthy maxillary sinuses, and the maxillary sinuses is completely showed in the images.

Exclusion Criteria: periodontal pathology and bony changes around the roots of upper posterior teeth, maxillary sinus pathology, root fractures or resorption, missing mandibular molars that resulted in extrusion of maxillary molars, and distorted or incomplete images.

Observation and Scoring

Data were collected using a Care Stream CBCT machine (Care Stream© 3D, 90 kV, 3.2 mA) with a scanning time of 15 seconds and a voxel size of 0.15 mm^3. CBCT images were viewed on an HP laptop with a 15.6-inch monitor (display resolution: 1366 × 768 pixels). Proximity and vertical relationships between root apices and the maxillary sinus floor (MSF) were assessed using the machine's built-in measurement software. The relationship between each root and the MSF was recorded in corrected planes (sagittal, coronal, and axial; see Figure 1a, 1b). The study employed a modified classification system based on, consisting of three classes: Class I where root apex is below the MSF (see Figure 2), Class II, where root apex is at the level of the MSF (see Figure 3), and Class III, where root apex is above and beyond the MSF (see Figure 4) [9].

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 26.0; IBM Corp., USA). Associations between root classification classes and patient age/gender were evaluated using chi- square tests.

Reliability Testing

Intra- and interexaminer reliability were assessed using Cohen's kappa test to quantify measurement error. From 102 cases, 30 were randomly selected and reevaluated 2 months after initial assessment, with examiners blinded to prior results. Agreement rates were 80.4% (intra- examiner) and 79.9% (inter-examiner).

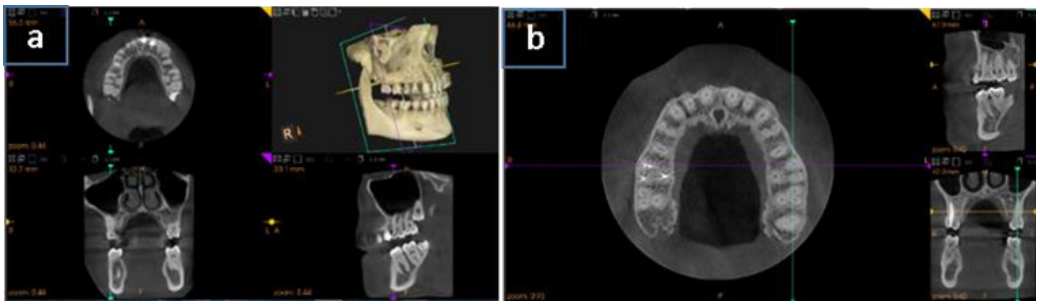

Figure 1(a): Axial, Coronal, Sagittal Planes and 3 D Bone Window; (b): Three Planes with Lines to Classify Root Relation.

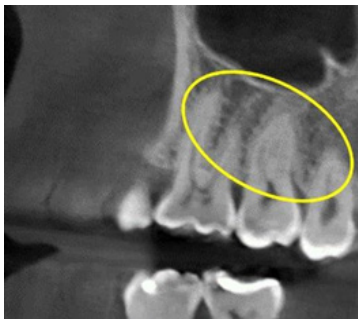

Figure 2: Class I Root Apex below MSF

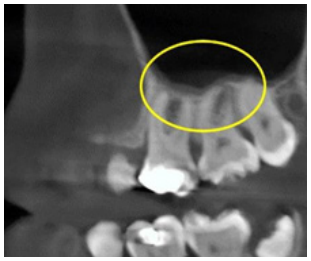

Figure 3: Class II Root Apex at MSF.

Figure 4: Class III Root Apex above MS

Table1: Intra and Inter Examiner Reliability Result (80.4%, and 79.9% Respectively.)

Intra Examiner				
	Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Kappa	0.804	0.088	6.638	0.000
N	30			
Inter Examiner				
Kappa	0.799	0.089	7.665	0.000
N	30			

Results

Sample Characteristics: The study sample consisted of 408 molars from 102 patients (45 males, 57 females) aged 20 to 63 years. A total of 1,224 roots were analyzed.

Root-MSF Relationship Classification: The modified classification revealed the following distribution: **Class I:** 517 roots (42%) were located outside the maxillary sinus floor (MSF), Class II: 446 roots (37%) had root apices in contact with the MSF, and Class III: 261 roots (21%) intruded into the sinus [9].

Frequency by Root Type:
Class I: Most frequent in the mesiobuccal (MB) roots of maxillary first molars (MM1; 111/204 roots, 54.5%), Class II: Most common in the distobuccal (DB) roots of maxillary second molars (MM2; 99/204 roots, 48.5%)., and Class III: Highest prevalence in the MB roots of MM2 (68/204 roots, 33.3%; see Table 2 and Figures 5, 6, 7).

Table2: Classification and Prevalence of Molars Roots, MB1: Most Prevalent as Class I, DB2: Most Prevalent as Class II, MB2: Most Prevalent as Class III

Tooth	**Root**	**Cl. I**	**Cl. II**	**Cl. III**
1st molar	**MB**	111\204 (54.5%)	62\204 (30.5%)	31\204 (15%)
	DB	107\204 (52.5%)	74\204 (36.2%)	23\204 (11.3%)
	P	98\204 (48%)	48\204 (23.5%)	58\204 (28.5%)
2nd molar	**MB**	44\204 (21.5%)	92\204 (45%)	68\204 (33.3%)
	DB	61\204 (29%)	99\204 (48.5%)	44\204 (21.5)
	P	96\204 (47%)	71\204 (35%)	37\204 (18%)

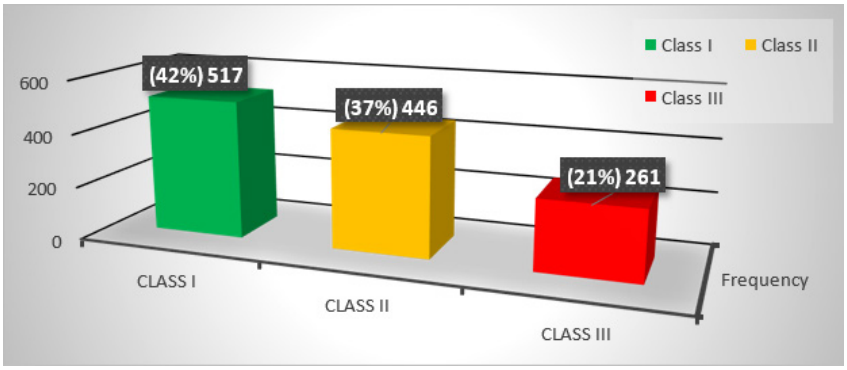

Figure 5: Overall Frequency of the Different Classes

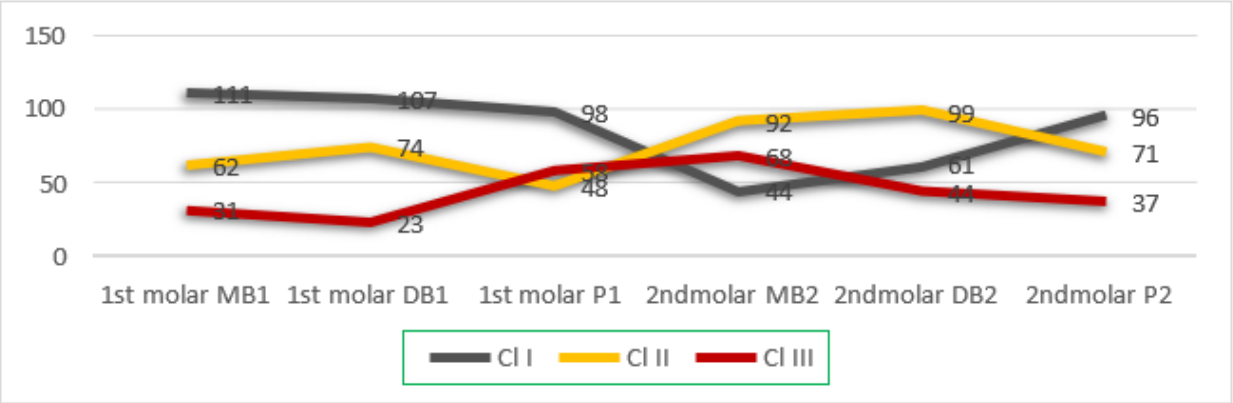

Figure 6: Prevalence and Relation of the Root's Classes with MSF.

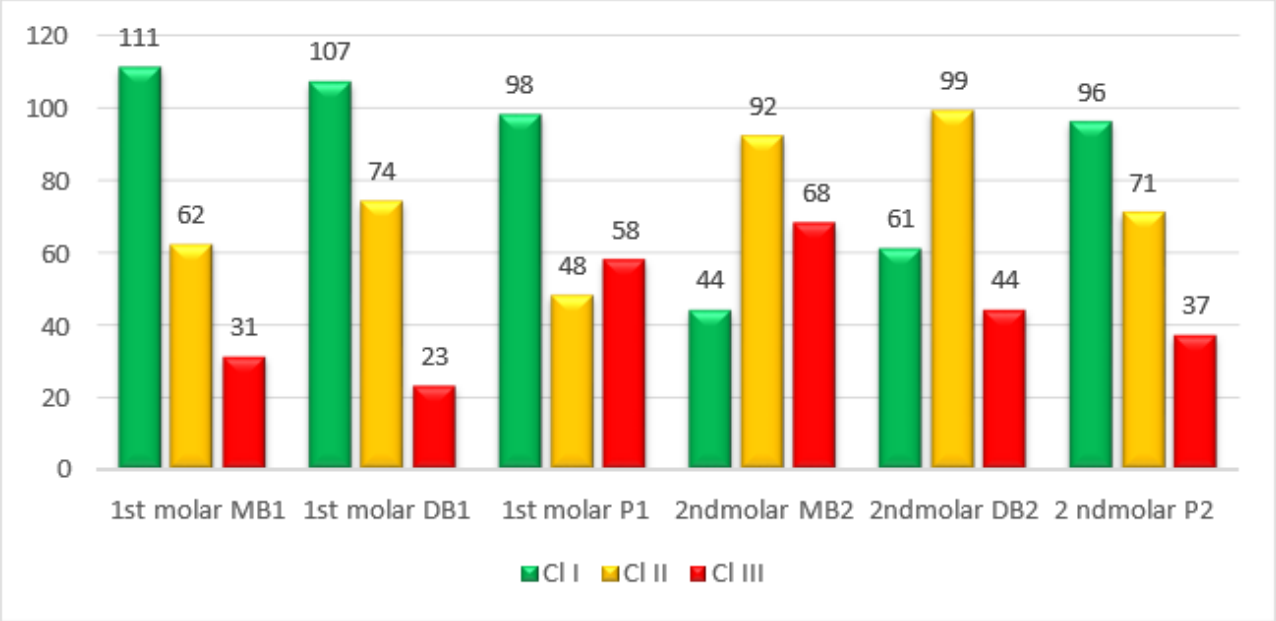

Figure 7: Prevalence and Relation of the Root's Classes with MSF.

Results by Age Group

The relationship between roots and the maxillary sinus floor (MSF) differed significantly between the younger (20–40 years) and older (41–63 years) age groups. Although the younger group generally exhibited closer root-to-MSF proximity (Class II and III), this trend was statistically significant only for specific roots:

Palatal Root of the Left Maxillary First Molar (LP1):

- Younger group: 19 Class II and 25 Class III roots (out of 102).
- Older group: 3 Class II and 7 Class III roots (*p* = .010).

Left Maxillary Second Molar (LM2) Roots:

- Mesio-buccal (LMB2): Younger: 34 Class II, 27 Class III; Older: 12 Class II, 6 Class III (*p* = .002).
- Disto-buccal (LDB2): Younger: 37 Class II, 19 Class III; Older: 13 Class II, 3 Class III (*p* = .005).
- Palatal (LP2): Younger: 24 Class II, 19 Class III; Older: 7 Class II, 3 Class III (*p* = .014) (See Table 3 for detailed distributions).

Results by Gender

The distribution of root-MSF relationships differed significantly between genders. Females exhibited a higher prevalence of Class I relationships (roots below the MSF), while males showed higher frequencies of Class II (roots contacting the MSF) and Class III (roots protruding into the sinus).

Overall Distribution

Females (*n* = 684 roots):

- Class I: 332 roots (48.5%)
- Class II: 228 roots (33.5%)
- Class III: 124 roots (18%). See table 4.

Males (*n* = 540 roots):

- Class I: 185 roots (34.2%)
- Class II: 218 roots (40.3%)
- Class III: 137 roots (25.5%). See table 4.

Statistically Significant Differences

The gender disparity in Class I prevalence was significant for:

Palatal Root of the Right Maxillary First Molar (RP1):

- Females: 35 Class I roots
- Males: 15 Class I roots (*p* = .019)

Distobuccal Root of the Right Maxillary Second Molar (RDB2):

- Females: 23 Class I roots Males: 8 Class I roots (*p* = .047; See table 5)

Non-Significant Trends

No significant gender differences were observed for their maxillary molar roots.

The elevated prevalence of Class II/III relationships in males (*p* > .05; see Table 5).

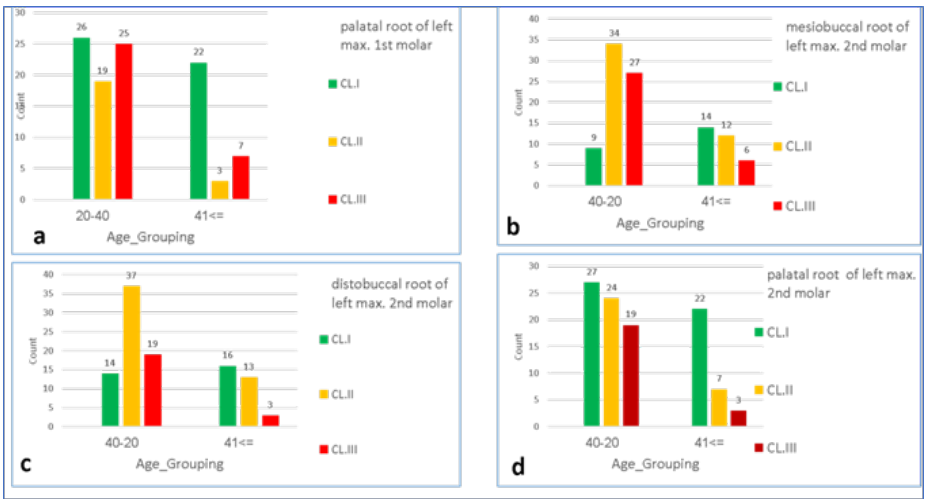

Figure 8: A significant difference for class II and class III in the case of: (a) the palatal roots of left first molars, (b) the MB2 roots, (c) DB2 roots, and (d) the palatal roots of left second molars.

Table 3: Prevalence of Age in Relation to Classification of Each Root:

ROOT	Class I		Class II		Class III		Total	Chi Sq.	Sig
	20-40	> 40	20-40	> 40	20-40	> 40			
RMB1	33	20	24	11	13	1	102	4.814	.090
RDB1	33	19	26	13	11	0	102	5.743	.057
RP1	32	18	19	7	19	7	102	.975	.614
RMB2	12	9	31	15	27	8	102	2.498	.287
RDB2	18	13	34	15	18	4	102	3.398	.183
RP2	30	17	27	13	13	2	102	2.793	.247
LMB1	35	23	23	4	12	5	102	5.317	.070
LDB1	33	22	27	8	10	2	102	4.286	.117
LP1	26	22	19	3	25	7	102	9.217	.010*
LMB2	9	14	34	12	27	6	102	12.558	.002*
LDB2	14	16	37	13	19	3	102	10.605	.005*
LP2	27	22	24	7	19	3	102	8.491	.014*
TOTAL	302	215	325	121	213	48	1224		

Chi sq. (Chi square test). Sig* (significance $P < 0.05$)

Table 4: Male and Female Results and Percentage of Roots in each Class:

ROOT	Class I		Class II		Class III		Total	Chi Sq	Sig.
	M	F	M	F	M	F			
RMB1	20	33	20	15	5	9	102	3.685	.158
RDB1	18	34	22	17	5	6	102	4.303	.116
RP1	15	35	15	11	15	11	102	7.929	.019*
RMB2	5	16	20	26	20	15	102	5.929	.052
RDB2	8	23	25	24	12	10	102	6.133	.047*
RP2	18	29	20	20	7	8	102	1.247	.536
LMB1	23	35	12	15	10	7	102	1.961	.375
LDB1	19	36	21	14	5	7	102	5.654	.059
LP1	17	31	9	13	19	13	102	4.587	.101
LMB2	10	13	17	29	18	15	102	2.416	.299
LDB2	12	18	22	28	11	11	102	.515	.773
LP2	20	29	15	16	10	12	102	.462	.794
TOTAL	185	332	218	228	137	124	1224		

Chi sq. (Chi square test). Sig.* (significance $P < 0.05$).

Table 5: Gender Groups Significance in Relation to Roots Classes:

Root	Class I		Class II		Class III	
	M	F	M	F	M	F
1MB	43	68	32	30	15	16
1DB	37	70	43	31	10	13
1P	32	66	24	24	34	24
2MB	15	29	37	55	38	30
2DB	20	41	47	52	23	21
2P	38	58	35	36	17	20
Total	**185/540 (34.2%)**	**332/684 (48.5%)**	**218/540 (40.3%)**	**228/684 (33.5%)**	**137/540 (25.5%)**	**124/684 (18 %)**

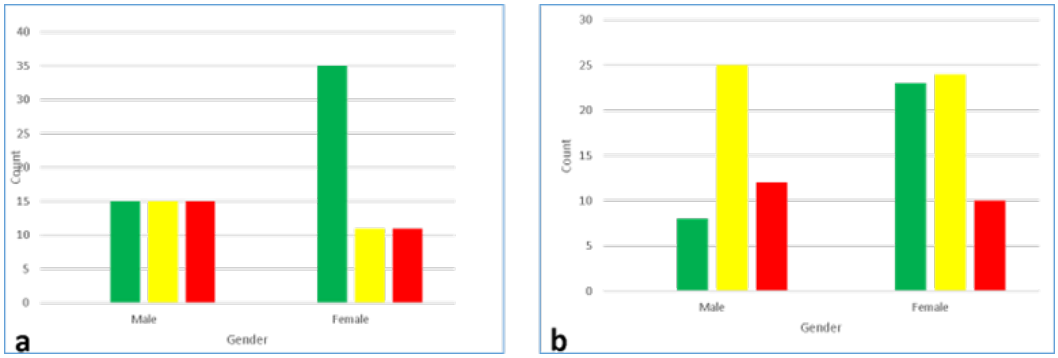

Figure 9: a) Palatal Roots of the Right First Molars Significant Difference Between Class I (P = 0.019), b) DB Roots of the Right Second Molars Significant Difference Between Class I (P = 0.047)

Discussion

This study utilized a three-class classification system to evaluate the vertical relationship between maxillary molar roots (MMRs) and the maxillary sinus floor (MSF) [4,9,21,22]. This system was selected for its simplicity and clinical utility, though methodologies for assessment vary across studies. For instance, while relied on coronal CBCT planes, used sagittal planes, and measured distances in all three planes but minimized the role of the coronal plane [9, 23,24].

Discrepancies in root-MSF relationships across imaging planes underscore the importance of multi-planar analysis [21,25].

Overall Assessment of the Proximity of MMR to MSF:

The Class I relation was found in 517 roots (42. %), Class II was in 446 roots (37 %), and 261 roots were being intruded into the sinus representing Class III relation (21 %). The class II and class III relation counted together 707 roots (57.7 %). These findings may lighten the close and critical relation of upper posterior teeth roots to MSF in both classes (II, III) and give alerts for operators to take precautions and avoid undesirable complications during surgical procedures of those roots, that are in a risky relation with the sinus. According to this study's classification, the most frequent roots for Class I relation were buccal roots of the maxillary first molars. For the Class II relation, the most frequent root was the distobuccal root of the maxillary second molar (DB2). For the Class III relation, the MB roots of the maxillary second molars were the most frequent, followed by the palatal roots of the maxillary first molars (Figure 6,7). The literature consistently demonstrates that maxillary molar roots exhibit closer proximity to the maxillary sinus floor (MSF) compared to premolar roots [8,26,27]. Notably, reported that approximately 50% of molar roots either protrude into the maxillary

sinus floor (MSF) compared to premolar roots [8,26,27]. Notably, reported that approximately 50% of molar roots either protrude into the maxillary sinus or directly contact the MSF [15]. This finding aligns with Jung and Cho's (2012) observation that buccal roots of molars most frequently intrude into the sinus space.

Found that the Class I relationship was the most common, whereas the closest roots (Class II) to the sinus were the palatal roots of the maxillary first molars (24.8%) and the MB roots of the maxillary second molars (21.6%) [22]. In contrast to this study found the MB root of the second molar showed the closest proximity to the sinus (34.3%), followed by the palatal root of the maxillary first molars (31.4%) [22]. Nevertheless, both studies agreed that the frequency of molar roots protruding into the sinus decreased with age. reported significantly lower rates of root protrusion (Class III = 9.5%) compared to this study (Class III = 21%), and a smaller proportion of roots located outside the sinus (Class I = 23.9% vs 42.1% in the current study) [16]. Similarly, found higher protrusion rates (42%) than this study (21%) [19,20]. These discrepancies may be attributed to differences in study populations, sample sizes, and CBCT analysis methods. Multiple studies concur that the mesiobuccal (MB) roots of maxillary second molars typically demonstrate the closest proximity to the maxillary sinus floor (MSF), with posterior teeth showing increased likelihood of root protrusion into the sinus. specifically identified the MB roots as closest to the MSF, followed by distobuccal (DB) roots and palatal roots of first molars, while also noting significant age-related effects - findings consistent with our results [28]. similarly reported the MB root as closest, though unlike our study, they found no significant gender or side differences, potentially due to population variations [29]. This study's findings partially align with, who observed greater MB root contact with the MSF but found no gender effect, and with regarding MB root proximity and age correlation [11,14]. Comparable results appear in and, all identifying MB roots as closest to the MSF with age-related patterns [8,30-32]. Reported nearly identical Class III prevalence (21.3% vs our 21%), while agreed on MB root proximity but differed regarding DB root positioning [15, 33]. Contrasting evidence exists: identified DB roots as closest, though Kwak et al. omitted gender analysis and Kilic et al. found no gender/side effects. Similarly, and Sarilita et al. (2024) reported palatal roots of first molars as most intrusive (44.33%, 34.2%, and 20% respectively), diverging from our findings - likely due to ethnic and methodological differences [4,9,26,34,35].

Influence of Age on the Relation of MMR to MSF:

This study revealed that age has a significant influence on the relation of molar roots to MSF. A closer relationship (Class II and III) was found in the younger age group. The first and second molars' roots of the younger age group (20-40) showed a closer relation to the MSF than the older age group (41-63) (table 3). Chi-square test showed a significant difference for class II and class III in the case of the palatal roots of left first molars ($P < 0.05$) and the MB, the DB and the palatal roots of left second molars ($P < 0.05$), (table 3, Figures 8a -d). This result gives an alert to pay attention while providing dental services such as upper molar extraction, endodontic treatment, or implant surgery in the younger age group. This study's findings are consistent with several other studies such as [4,14,21,22,32]. On the contrary, other studies found no effect of age on the proximity of molar roots to the MSF [11,24,36]. n distance between the floor of the sinus and the maxillary molars' roots (Kim et al. 2007) [37-39].

Gender Differences in Root-MSF Relationships

Gender was found to be an influencing factor on root-MSF relationships (Table 5). Females showed higher prevalence of Class I relationships, with particularly significant differences ($p < 0.05$) observed in: the palatal roots of right maxillary first molars, and the distobuccal (DB) roots of right maxillary second molars (Table 5, Figures 9 a & b) These findings suggest males generally exhibit closer root-MSF proximity than females, consistent with studies reporting larger sinus volumes and closer root relationships in males [4,40]. However, several studies found no significant gender differences Shokry et al., 2016 [9,11,22,36,41]. Notably, some studies report contradictory findings, with suggesting closer root-sinus relationships in females [14, 22, 42].

Conclusion

Key Findings

Prevalence of Root-MSF Relationships:

- Class I (roots below MSF): 517 roots (42.1%).
- Class II (roots contacting MSF): 446 roots (37%).
- Class III (roots protruding into sinus): 261 roots (21%).

The combined prevalence of Class II/III (57.7%) highlights the close anatomical proximity of MMRs to the sinus, warranting surgical caution.

Root-Specific Trends:

- Class I: Most frequent in buccal roots of maxillary first molars.
- Class II: Predominant in distobuccal (DB) roots of maxillary second molars.
- Class III: Most common in mesiobuccal (MB) roots of maxillary second molars, consistent with

Jung and Cho (2012) but contrasting with, who reported palatal roots of first molars as closest [35].

Comparisons with Prior Research

Consistencies:

- Age-related decline in root protrusion [22, 28].
- MB roots of second molars as most frequently intruding [8, 33].
- Similar Class III prevalence (21%) to [15].

Discrepancies:

- Lower Class III rates vs. (42%), possibly due to population or methodological differences [19, 20].
- Divergent findings on palatal roots may reflect ethnic variability [4].

Limitations and Future Directions

- Methodological heterogeneity (e.g., imaging planes, software) complicates cross-study comparisons.
- Demographic factors (e.g., ethnicity, age distribution) may explain conflicting results (e.g., gender effects in [11] vs. this study).
- Standardized protocols for CBCT analysis are needed to enhance reproducibility.

Recommendations

Clinical Awareness

Dental clinicians, particularly those performing oral surgery, endodontic therapy, implant placement, and orthodontic treatment, should recognize the close proximity between maxillary molar buccal roots and the maxillary sinus floor (MSF) to minimize iatrogenic complications.

Future Research

Further studies across diverse geographical populations are recommended to:

- Validate and generalize these findings
- Strengthen evidence for clinical decision-making
- Explore potential ethnic or regional variations in root-MSF relationships

Preoperative Protocols

Routine cone-beam computed tomography (CBCT) assessment should be considered for procedures involving maxillary posterior teeth to evaluate individual anatomical relationships with the MSF [43-46].

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