Original Article

Anatomical relationship between roots of maxillary posterior teeth and maxillary sinus using cone-beam computed tomography

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ABSTRACT

Aim: Maxillary sinusitis of odontogenic origin accounts for approximately 10%–12% of maxillary sinusitis cases. The primary objective of the present study was to analyze the vertical relationship between the maxillary posterior roots and the adjacent maxillary sinus floor (MSF) in the Indian population using cone-beam computed tomography. The secondary objective was to correlate the data with age and gender.

Materials and Methods: The shortest distance between 452 maxillary posterior teeth and the adjacent border of MSF was measured. The data were divided into three groups. Group IS included maxillary posterior teeth roots protruding into the sinus, Group CO included root apices contacting the MSF, and Group OS included root apices not contacting the MSF. The data obtained were correlated with age and gender.

Results: The vertical distance of the root apices of second premolars from the MSF was significantly lesser compared to the root apices of first premolars ($P < 0.05$). The difference between the vertical distance of buccal roots and palatal roots (PRs) of first molar from the MSF was significantly more ($P < 0.05$). Majority of the roots of posterior teeth were located below the MSF border (Type OS). Type IS was most frequently seen for PRs of maxillary first molars (29.12%). The frequency of Type IS decreased with increasing age. The distance between the posterior root apices and the adjacent border of the MSF was found to be more in males compared to females.

Conclusion: The PRs of maxillary first molars were found to be closest to the MSF. Variation in the vertical relationship was found by age and gender.

Keywords: Cone-beam computed tomography, endodontic therapy, maxillary sinus, sinusitis, tooth apex

INTRODUCTION

The maxillary sinus is highly prone to invasion by pathogenic organisms through the nasal ostium or, occasionally, the oral cavity. Maxillary sinusitis of odontogenic origin accounts for approximately 10%–12% of maxillary sinusitis cases.[1] Endodontic therapy, extraction of maxillary teeth, orthodontic treatment, and odontogenic infections can cause complications of maxillary sinus.[2,3] According to recent studies, maxillary sinusitis is associated with dental pathologies in more than 50% of cases.[3] Alterations in maxillary sinus may be related to several sources of odontogenic infection such as periapical lesions, periodontal bone loss, extensive caries, defective restorations, endodontic treatments, bone grafts and dental implants, and iatrogenesis during surgical procedures.[3] Several procedural errors during nonsurgical endodontic therapy (overinstrumentation, overirrigation, and overobturation) and surgical endodontic procedures (root resection, curettage, and surgical retrieval of instruments separated beyond the tooth apex) may contribute toward pathologic alterations in the maxillary sinus leading

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to maxillary sinusitis of odontogenic origin, endo-antral syndrome, and traumatic alterations, which account for increased complexity for dentists and otolaryngologists.[4-7]

Cone-beam computed tomography (CBCT) is a three-dimensional (3D) imaging technique that contributes toward effective and successful clinical diagnosis and treatment planning by virtue of accurate evaluation of the anatomical features. CBCT can evaluate the relationship between the root apices of maxillary posterior teeth and maxillary sinus.[7] Various studies have assessed the proximity of the maxillary posterior teeth to the maxillary sinus floor (MSF).[7-10] Very few studies have been conducted on the Indian population, but the correlation with age and gender has not been determined.[11] Thus, the primary objective of the present study was to analyze the vertical relationship between the posterior roots and the adjacent MSF in the Indian population using CBCT images. The secondary objective was to correlate the data with age and gender.

MATERIALS AND METHODS

The study material was composed of dental CBCT images collected from the archives of a private dentomaxillofacial radiology center. Written informed consent was obtained from the individuals for using the data for research purpose. The study was exempt from approval by an institutional review board because of the retrospective nature.

Cases presenting with the following findings were included for analysis: (i) patients of age >21, (ii) presence of maxillary permanent premolar and molar teeth on CBCT scans, (iii) fully erupted teeth with fully formed apexes, (iv) maxillary posterior teeth with neither definitive root resorption nor bony destruction around the teeth, and (v) complete MSF with no damage by disease. Cases presenting with the following findings were excluded: (i) presence of periapical or periradicular lesions, (ii) teeth which had previously undergone orthodontic treatment, and (iii) images with artifacts.

CBCT images of 452 teeth met the inclusion and exclusion criteria. This included 136 maxillary first premolars (MFPs), 118 maxillary second premolars (MSPs), 103 maxillary first molars (MFMs), and 95 maxillary second molars (MSMs). The patients were divided into three groups: 21–40-year group, 41–60-year group, and >60-year group.

Cone-beam computed tomography image evaluation

The vertical relationship between posterior roots and the MSF was classified into three categories according to Tian *et al*. [Figure 1]:[5]

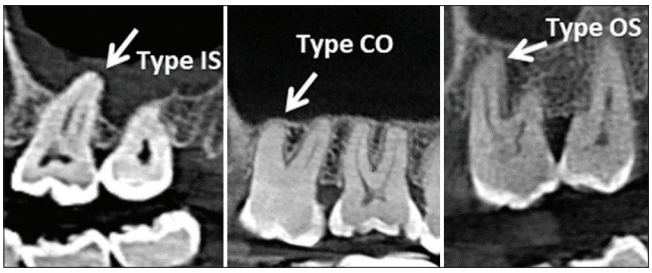

Figure 1: Cone-beam computed tomography images of three vertical relationships between maxillary posterior teeth and maxillary sinus floors

- Type IS: The root tips extending above/inside the MSF
- Type CO: The root contacting with the MSF
- Type OS: The root extending below/outside the sinus floor.

The CBCT images were assessed using Carestream 3D Imaging Software (Carestream Dental LLC, Atlanta, GA) with the following parameters: exposure – 90 KV, 4 mA, 15s; dose – 733 mGy.cm^2; and voxel size – 150 μm × 150 μm × 150 μm.

The methods used to analyze and measure were as follows:

Evaluation of the vertical relationship between each root of the maxillary posterior teeth and the MSF was done in sagittal and coronal CBCT planes simultaneously and categorized into the three types. The priority order of the three types was Type IS, Type CO, and Type OS. So, if the relationship was Type IS in the sagittal plane and Type CO in coronal plane; then, it was categorized under Type IS.

The shortest distance of the root apices of the maxillary posterior teeth to the closest border of the MSF was measured in both sagittal and coronal CBCT planes simultaneously. The values that were smaller in these two measurements for the same root were recorded [Figure 2]. A negative value was recorded if the root was protruding inside the sinus floor.

The evaluation was done by two experienced endodontists, at 1-week interval, to ensure reliability of data.

Statistical analysis

The association between the measurements and the age and sex was assessed using one-way ANOVA and independent *t*-test, respectively. Chi-square test was used to determine the association between the frequencies of type of relationship of root and age and sex. The intra- and interobserver reliabilities were assessed using Cohen's kappa statistical analysis. $P \leq 0.05$ was considered statistically significant.

Figure 2: Cone-beam computed tomography images showing measurement of shortest distance between the root apices and adjacent border of maxillary sinus floor in sagittal and coronal planes. The values that were smaller in these two measurements for the same root were recorded

RESULTS

The kappa value for the intraobserver agreements was 1.000. Regarding the interobserver agreement, the kappa values were 1.000 for first PM, second PM, first molar, and distobuccal (DB) root of second molar and 0.997 for mesiobuccal (MB) and palatal (P) roots of second molar. There was an excellent inter- and intraobserver agreement. The mean vertical distances from the palatal and buccal roots of MFPs to the MSF were 6.15 ± 3.59 mm and 6.16 ± 3.45 mm, respectively [Table 1].

Statistically significant differences were found between first premolars and second premolars ($P < 0.05$) and on comparing MB roots (MBRs) and DB roots (DBRs) of first molar with P roots of first molar with respect to the vertical distance from the border of sinus floor ($P < 0.05$).

Majority of the roots of posterior teeth were located below the border (Type OS) of MSF. The highest percentage was for maxillary first premolar (97.79%). Type IS was most frequently seen in respect to palatal roots (PRs) of maxillary first molars (29.12%), followed by PRs of maxillary second molars (17.89%), as shown in Figure 3.

The distances from root apices to the adjacent border of the sinus floor increased with increasing age for each tooth.

Analysis of the frequency of Type IS of roots according to age [Table 2] showed that the frequency of Type IS decreased with increasing age. The differences in the distances and the frequencies of Type IS were statistically significant for MBRs and DBRs of maxillary first molar and MBRs of maxillary second molar ($P < 0.05$).

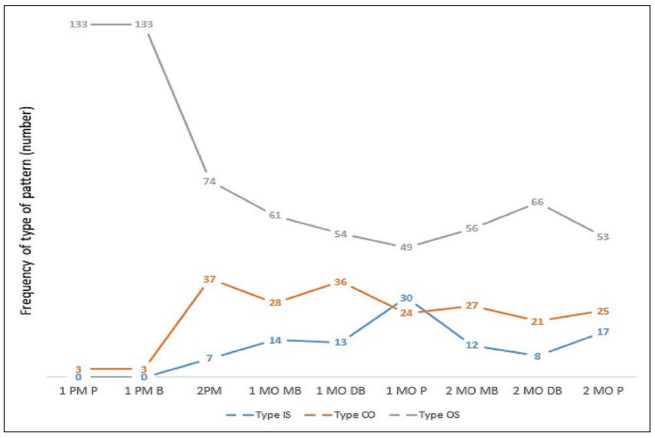

Figure 3: Frequency of relationship between type of posterior roots and maxillary sinus floor ($P < 0.05$). 1PM P: First premolar palatal; 1PM B: First premolar buccal; 1MO DB: First molar distobuccal; 1MO MB: First molar mesiobuccal; 1MO P: First molar palatal; 2MO DB: Second molar distobuccal; 2MO MB: Second molar mesiobuccal; 2MO P: Second molar palatal; 2PM: Second premolar

The vertical relationship also was correlated with gender [Table 3]. Overall, the distance between the posterior root apices and adjacent border of MSF was more in males compared to females, but the results were statistically significant only for MFPs (buccal roots) and MSPs.

DISCUSSION

The close proximity of maxillary posterior teeth to the MSF results in various complications during the dental treatment procedures. Kim *et al*. reported a case which demonstrated that root canal overfilling by Calcipex II in the periapical region of maxillary premolar and molar resulted in chronic maxillary sinusitis in 2 years.[4]

In the present study, the vertical relationship between the posterior roots and the adjacent MSF in the Indian population was studied.

Orthopantograms are the most frequently used radiographs for studying maxillary sinus and posterior teeth. Panoramic radiography has many disadvantages (superimposition of anatomical structures, lack of cross-sectional information, and undesirable magnification) which may give unreliable results when evaluating the relationship between the maxillary posterior teeth roots and maxillary sinus.[2] Thus, in the present study, CBCT images were studied retrospectively.

The results showed that overall the frequency of Type OS was maximum for all the roots of maxillary posterior teeth. Majority of the roots of MFPs (97.79%) had Type OS pattern, which is consistent with the previous studies.[5-7,12,13] The frequency of Type OS was relatively lower for MSPs when

Table 1: Measurements between the maxillary posterior teeth and the adjacent maxillary sinus floor (mm) according to age

	21-40 years	41-60 years	>60 years	Total
1 PM P				
n	51	69	16	136
Mean (SD)	5.67 (3.52)^{a,A}	6.49 (3.78)^{a,A}	6.20 (2.91)^{a,A}	6.15 (3.59)
1 PM B				
n	51	69	16	136
Mean (SD)	5.80 (3.72)^{a,A}	6.34 (3.33)^{a,A}	6.51 (3.24)^{a,A}	6.16 (3.45)
2 PM				
n	55	54	9	118
Mean (SD)	2.28 (3.26)^{b,A}	2.68 (2.84)^{b,A}	2.87 (3.34)^{b,A}	2.51 (3.06)
1MO MB				
n	40	53	10	103
Mean (SD)	0.72 (2.90)^{a,A}	2.32 (2.29)^{a,B}	3.07 (2.81)^{a,C}	1.77 (2.71)
1 MO DB				
n	40	53	10	103
Mean (SD)	0.94 (2.94)^{a,A}	2.21 (2.40)^{a,B}	2.87 (3.10)^{a,C}	1.78 (2.76)
1 MO P				
n	40	53	10	103
Mean (SD)	0.22 (3.19)^{b,A}	0.72 (3.35)^{b,A}	2.63 (3.46)^{b,A}	0.71 (3.34)
2 MO MB				
n	40	47	8	95
Mean (SD)	0.73 (2.68)^{a,A}	2.22 (2.60)^{a,B}	3.44 (3.27)^{a,C}	1.70 (2.81)
2 MO DB				
n	40	47	8	95
Mean (SD)	1.18 (2.86)^{a,A}	2.60 (2.60)^{a,B}	3.95 (3.75)^{a,C}	2.11 (2.92)
2 MO P				
n	40	47	8	95
Mean (SD)	0.41 (2.94)^{a,A}	1.78 (2.71)^{a,B}	3.16 (2.57)^{a,C}	1.32 (2.90)

Different superscript lowercase letters in the same column indicate a significant difference ($P<0.05$); different superscript uppercase letters in the same row indicate a significant difference ($P<0.05$). 1PM P: First premolar palatal; 1PM B: First premolar buccal; 1MO DB: First molar distobuccal; 1MO MB: First molar mesiobuccal; 1MO P: First molar palatal; 2MO DB: Second molar distobuccal; 2MO MB: Second molar mesiobuccal; 2MO P: Second molar palatal; 2PM: Second premolar

Table 2: Frequency of Type IS, Type CO and Type OS according to age

Type tooth	21-40 years (%)			41-60 years (%)			>60 years (%)		
	IS	CO	OS	IS	CO	OS	IS	CO	OS
1 PM P	0	0	100	0	2.98	97.01	0	6.25	93.75
1 PM B	0	1.88	98.11	0	1.49	98.50	0	6.25	93.75
2PM	10.90	32.72	56.36	1.85	27.77	70.37	0	44.44	55.55
1MO MB*	32.50	30	37.50	1.88	38.18	67.92	0	0	100
1 MO DB*	30	32.50	37.50	1.88	39.62	58.49	0	20	80
1 MO P	35	10.25	16.40	28.30	24.52	47.16	10	10	80
2 MO MB*	25	30	45	4.25	27.65	68.08	0	25	75
2 MO DB	15	12.30	22.55	4.25	17.02	78.72	0	12.5	87.5
2 MO P	25	37.5	37.5	14.89	17.02	68.08	0	25	75

*Significant at $P<0.05$.1PM P: First premolar palatal; 1PM B: First premolar buccal; 1MO DB: First molar distobuccal; 1MO MB: First molar mesiobuccal; 1MO P: First molar palatal; 2MO DB: Second molar distobuccal; 2MO MB: Second molar mesiobuccal; 2MO P: Second molar palatal; 2PM: Second premolar; IS: Root tips extending above/inside the maxillary sinus floor; CO: Root contacting with the maxillary sinus floor; OS: Root extending below/outside the sinus floor

compared with MFPs. Type IS and Type CO were more frequently observed in MSPs as compared to MFPs. This is in concurrence with the findings of Gu *et al*. and Tian *et al*.[5,7] This indicates that the roots of MFPs have very little relationship with the MSF, whereas MSPs are relatively closer to the MSF. For maxillary molars, Type IS was more frequently observed for PRs of MFMs (29.12%), indicating that dentists should be more cautious while treating these teeth to prevent any damage to MSF in this region. This is in accordance with the previous studies by Gu *et al*. and Tian *et al*. done in the Chinese population.[5,7] Following the PRs of MFMs, the frequency of Type IS was more with respect to the PRs (17.89%) of MSMs. This is different from the studies by Gu *et al*. and Tian *et al*. in which the frequency of root

Table 3: Measurements between the maxillary posterior teeth and the adjacent maxillary sinus floor (mm) according to gender

	1 PM P	1 PM B	2 PM	1 MO MB	1 MO DB	1 MO P	2 MO MB	2 MO DB	2 MO P
Male, mean (SD)	6.64 (3.70)	6.70 (3.67)	3.18 (3.16)	2.18 (2.74)	1.26 (3.64)	1.26 (3.64)	1.73 (3.08)	2.12 (3.27)	1.48 (3.44)
Female, mean (SD)	5.46 (3.34)	5.40 (3.00)	1.80 (2.82)	1.35 (2.63)	1.48 (2.55)	0.14 (2.91)	1.66 (2.52)	2.10 (2.53)	1.14 (2.24)
P	0.057	0.030*	0.014*	0.117	0.278	0.089	0.905	0.978	0.568

*Significant at $P<0.05$. 1PM P: First premolar palatal; 1PM B: First premolar buccal; 1MO DB: First molar distobuccal; 1MO MB: First molar mesiobuccal; 1MO P: First molar palatal; 2MO DB: Second molar distobuccal; 2MO MB: Second molar mesiobuccal; 2MO P: Second molar palatal; 2PM: Second premolar; SD: Standard deviation

protrusions of MBRs of MSMs followed the PRs of MFMs.[5,7] A study conducted on Brazilian population by Pagin *et al*. showed that the percentage of root protrusions (Type IS) for MBRs, DBRs, and PRs of MFMs was 3.2%, 1.8%, and 5.5%, respectively, and for MBRs, DBRs, and PRs of the MSMs was 12.9%, 8.3%, and 4.1%, respectively.[6] Jung and Cho evaluated the Korean population for the same and reported that the root protrusions were 32.5% and 30.1% for MBRs and DBRs of MFMs, respectively, and 36.7% and 34.3% for MBRs and DBRs of MSMs, respectively.[8] Ok *et al*. found that the root protrusions in Turkey's population were 34.2% for MBRs of MFMs and 30.9% for MBRs and DBRs of MSMs.[14] All these results are different from the present study. This difference indicates that ethnic variation plays an important role in influencing the relationship between the MSF and maxillary posterior teeth roots.

In this study, it was found that the root apices of MFPs had the maximum distance from the MSF (6.15 ± 3.59 mm). This finding was consistent with previous studies on Russian, Chinese, Turkey, and Brazilian populations, indicating that endodontic treatments of MFPs have little impact on maxillary sinus.[5,7,10,12,13] The results of the present study showed that PRs of MFMs were closest to the MSF, i.e., had minimum distance from the floor of maxillary sinus (0.71 ± 3.34 mm). This was in agreement with a study conducted in Japanese population by Yoshimine *et al*.[15] However, other reports in the Chinese and Brazilian population showed that MBRs of MSMs were closest to the MSF.[5,7,10] Kilic *et al*. and Kwak *et al*. found that minimum distance was observed in DBRs of MFMs in Korean and Turkey populations.[13,16] A possible explanation for this difference could be the ethnic variation and use of different measuring methods and software for evaluating the distance between the posterior root apices and MSF.

The mean distances of all the root apices of maxillary posterior teeth to the adjacent border of MSF increased with increasing age. Similar findings were reported by Gu *et al*. and Tian *et al*. in the Chinese population.[5,7] Thus, it can be concluded that damage to maxillary sinus due to iatrogenic errors and odontogenic infections is more likely in younger populations since the maxillary posterior teeth are more closely associated with maxillary sinus in younger individuals.

In the present study, the proximity of posterior tooth apices to MSF was more in females compared to males but without any statistical significance except for MFPs (buccal roots) and MSPs. Von Arx found that, on an average, premolar roots were situated closer to the maxillary sinus in males than in females but without reaching statistical significance.[9] Gu *et al*. also reported no statistical difference between males and females regarding the proximity of maxillary posterior teeth to MSF.[7]

CONCLUSION

Within the limitations of this study, the following may be concluded:

- The PRs of MFMs appeared to be the closest to the MSF, followed by PRs of MSMs
- The frequency of the root apices protruding inside the MSF (Type IS) decreased with age
- The maxillary posterior roots are closer to the MSF in females compared to males.

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Conflicts of interest

There are no conflicts of interest.

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