ORIGINAL ARTICLE

Anatomical proximity of maxillary teeth and local factors associated with the thickness of the maxillary sinus mucosa: a retrospective study

ABSTRACT

Aim: *This cross-sectional study aimed to assess the proximity of root apexes to the maxillary sinus and to verify the correlation between sinus mucosal thickening with the distance from the root apex to the sinus floor, endodontic treatment, age, tooth, sex, and presence of periapical lesion.*
Methodology: *169 cone-beam computed tomography images were selected, and 696 teeth were assessed, 600 without endodontic treatment, and 96 endodontically treated. The images were initially classified according to the study conducted by Kwak et al. (2004) to assess the proximity of the tooth roots to the maxillary sinus, and multiple logistic regression was subsequently applied to identify probable factors influencing the thickening of the sinus mucosa.*
Results: *The vertical relationships between tooth roots and the sinus floor among the second premolars indicated a predominance of classification I (57.7%); whereas, in the first and second molars there was a predominance of types II (48.4%) and III (34.2%), respectively. The logistic regression did not indicate significant relationships between sinus mucosal thickening and the distance from the root apexes to the sinus floor, presence of endodontic treatment, and type of tooth ($p>0.05$). Age, presence of periapical lesions, and sex were associated with the presence of sinus thickening ($p<0.05$; odds ratio=1.03, 2.99, and 5.11, respectively).*
Conclusions: *The presence of thickening in maxillary sinuses was correlated with the following factors: age, sex, and presence of periapical lesions.*

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Introduction

The desired outcome for any endodontic treatment involves preventing or eradicating pulp and periradicular infections and complete sealing of the root canal system, providing comfort and a better quality of life for patients subject to this type of therapy (1). Currently, it is possible to observe with greater clarity the proximity of the root apexes of posterior upper teeth to the maxillary sinus. Cone-beam computed tomography (CBCT) is currently considered one of the most accurate image resources in the visualization of structures - such as the maxillary sinus - and possible changes in the sinus mucosa. Also, CBCT avoids inconveniences during the analyses, such as overlapping images, distortions, or vertical and horizontal enlargements (7, 10), becoming valuable and effective for determining the clinical relationship between the maxillary sinus floor and the root apexes of posterior upper teeth (11-13), increasing the number of cases diagnosed due to image accuracy (10).

Changes in the maxillary sinus mucosa generated by odontogenic infections are the result of the anatomical relationship between teeth and sinus. The roots of the posterior upper teeth are usually in close opposition to the maxillary sinus, with their apexes being projected towards the floor of this structure. This fact causes elevations or prominences in the thin layer of bone that separates them, which is considered a fusion of the lamina dura and the floor of the maxillary sinus (2). It is known that the upper first and second molars are usually pointed out as the teeth with greater proximity to the maxillary sinus (3-5). In addition, these two types of teeth have a higher prevalence of periapical lesions, when compared with the other teeth of the oral cavity (even when already endodontically treated), due to the high probability of having an extra canal (6). These lesions generate the risk of dissipating bacterial infections, thus damaging the maxillary sinus floor due to the extent of periradicular lesions when present (7).

Odontogenic sinusitis is characterized by chronic inflammation of the paranasal sinuses. It occurs when the Schneiderian membrane is irritated or perforated, as a result of dental infections, maxillary trauma, a foreign body within the maxillary sinus, supernumerary teeth, or periapical granuloma (8). The deposition of foreign substances - including those used in endodontics - when inside the maxillary sinus, can also give rise to various pathophysiological responses, and induce chronic inflammation. These foreign bodies can promote sinus pain and pressure, acute and chronic sinusitis resulting from irritation and thickening of the mucous membranes of the sinus, pain during chewing, and tenderness on palpation (9). Based on the above, the goals of this retrospective study were to assess the proximity of root apexes to the maxillary sinus and to verify the correlation between sinus membrane thickening with the distance from the root apex to the sinus floor, endodontic treatment, age, tooth, sex, and presence of periapical lesion.

Materials and Methods

After approval by the local Research Ethics Committee (approval number 773.236), 169 CBCT images obtained from a private clinic of oral and maxillofacial radiology were assessed. Each tomographic image was analyzed in parasagittal sections of the upper premolar and molar regions, both on the left and right sides.

To compose the sample for the study, the images were selected based on the following inclusion criteria: images of patients who had at least 20 years of age; and that provided a complete view of the maxillary sinus and the roots of the posterior upper teeth. Since this study was done using CBCT images and there was no way to confirm periodontal diseases based only on the images, teeth with periodontal diseases were not excluded.

The sample calculation was performed using the GPower 3.1.9.4 software (Heinrich-Heine-Universität Düsseldorf , Germany) (14) and the incidence of root protrusion within the maxillary sinus of upper second premolars and upper first and second molars, with the maxillary sinus as the primary outcome. Based on the study conducted by Jang et al (15) a power of 0.80 and an α level of 0.05 were used to detect a difference in

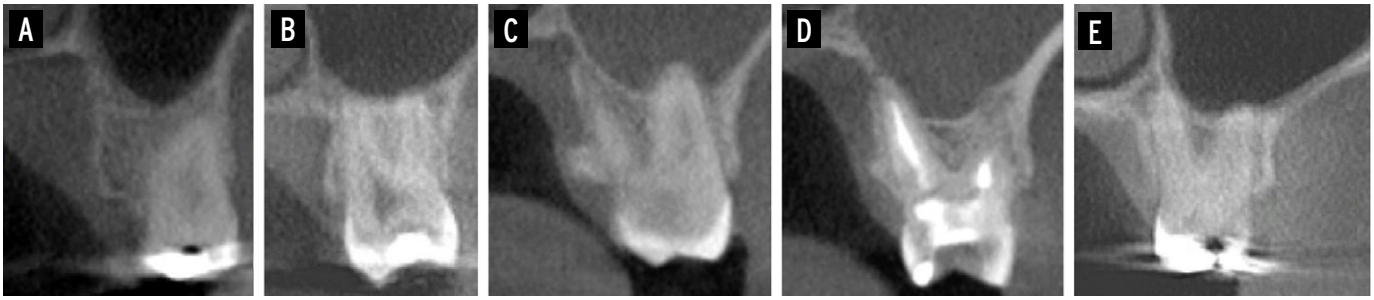


Figure 1
CBCT images exemplifying the different anatomic relationship between maxillary sinuses and molars.
A) Type I=maxillary sinus floor located above the buccal and palatal root apexes**; B)** Type II=maxillary sinus floor in contact with buccal and palatal root apexes; **C)** Type III=apical projection of one or two buccal roots into the sinus floor; **D)** Type IV=apical projection of palatal roots into the sinus floor; **E)** Type V=apical projection of the buccal and palatal roots into the sinus floor.

proportions of 0.0714 between groups. To that end, 660 teeth were needed. In the present study, 696 teeth were scanned, 600 had had no endodontic treatments, and 96 had been endodontically treated.
In the first analysis, we classified the images according to the tooth roots' proximity to the maxillary sinuses. Thus, patients' molars and premolars of the right and left hemi-faces were classified according to the study conducted by Kwak et al. (16). The molars were classified as: type I=maxillary sinus

Table 1

Vertical relationships between the sinus floor and the roots of the upper teeth

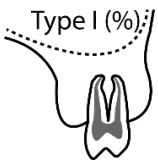
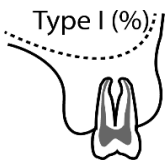
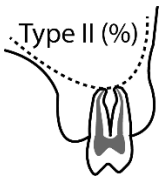
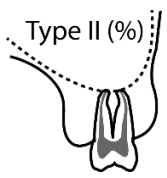
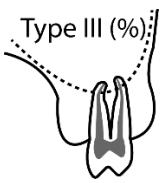
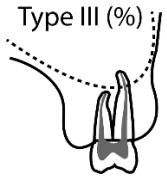
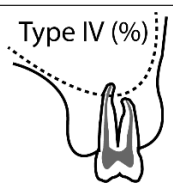
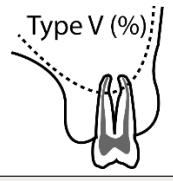
	Second premolars		First molars	Second molars
	112 (57.7)		63 (28)	92 (33.2)
	71 (36.5)		109 (48.4)	73 (26.3)
	11 (5.6)		28 (12.4)	95 (34.2)
	-		19 (8.4)	9 (3.2)
	-		6 (2.6)	8 (2.8)
Total	**194 (100%)**		**225 (100%)**	**277 (100%)**

Figure 2
CBCT images exemplifying the different anatomic relationship between maxillary sinuses and Second premolars. **A)** Type I=maxillary sinus floor located above the root apexes; **B)** Type II=maxillary sinus floor in contact with the root apexes; **C)** Type III=apical projection of the root into the sinus floor.

floor located above the buccal and palatal root apexes; type II=maxillary sinus floor in contact with buccal and palatal root apexes, but without projection of the roots into the floor of the sinus (laterally projected to the maxillary sinus); type III=apical projection of one or two buccal roots into the sinus floor; type IV=apical projection of palatal roots into the sinus floor, and type V=apical projection of the buccal and palatal roots into the sinus floor (Table 1, Figure 1).

For the second premolars, the classification was adapted as follows: type I=maxillary sinus floor located above the root apexes; type II=maxillary sinus floor in contact with the root apexes, but without apical projection into the sinus floor (roots laterally projected into the sinus); type III=apical projection of the root into the sinus floor (Table 1, Figure 2). For the evaluator's calibration, an intra-observer reliability analysis was performed using Weighted Cohen's Kappa coefficient of agreement until indexes above 0.9 were obtained.

A second analysis was performed using multiple logistic regression to determine the relationships between the thickening of the sinus mucosa and the distance from the root apex to the sinus floor, endodontic treatment, age, tooth, sex, and presence of periapical lesions. To that end, 96 teeth endodontically treated were assessed, and 52 untreated teeth from the initial sample of 600 teeth were selected at random. This way, the sample was composed of 139 molar roots endodontically treated, and 117 without previous endodontic treatments. The presence of

Table 2

Vertical relationships between the sinus floor, presence/absence of thickening, treatment, and roots of the upper teeth

	Type I	Type II	Type III	Type IV	Type V	Total
Second premolars (194)						
Treated (n)	24	16	4	-	-	44
Thickening (%)	13 (54.1)	4 (66.6)	1 (25)	-	-	18 (40.9)
Untreated (n)	88	55	7	-	-	150
Thickening (%)	20 (22.7)	13 (23.6)	1 (14.2)	-	-	34 (22.6)
First molars (225)						
Treated (n)	14	6	3	2	2	27
Thickening (%)	6 (42.8)	5 (83.3)	0 (0)	0 (0)	0 (0)	11 (40.7)
Untreated (n)	49	103	25	17	4	198
Thickening (%)	12 (24.4)	30 (29.1)	7 (28)	7 (41.17)	1 (25)	57 (28.78)
Second molars (277)						
Treated (n)	9	3	9	2	2	25
Thickening (%)	3 (33.3)	3 (100)	1 (11.1)	1 (50)	1 (50)	9 (36)
Untreated (n)	83	70	86	7	6	252
Thickening (%)	25 (30.1)	17 (24.2)	20 (23.25)	5 (71.42)	0 (0)	67 (26.5)

Table 3

Simple and multiple logistic regression of the association between the presence of maxillary sinus thickening and the explanatory variables

Explanatory variables	Non-adjusted odds ratio (95% CI)	*p*-value	Adjusted odds ratio (95% CI)	*p*-value
Age	1.0299 (1.00 to 1.06)	0.0222	1.0301 (1.00 to 1.06)	0.0442
Periapical Lesion				
Present	3.0612 (1.48 to 6.35)	0.0026	2.9951 (1.29 to 6.97)	0.0109
Absent	1		1	
Endodontic Treatment				
Present	1.7783 (0.85 to 3.72)	0.1257		
Absent	1			
Teeth				
Premolars	1.0417 (0.52 to 2.09)	0.9083		
First molars	1.2231 (0.60 to 2.51)	0.5827		
Second molars	0.7725 (0.37 to 1.63)	0.4984		
Anatomical classification	0.7361 (0.52 to 1.05)	0.0901		
Sex				
Male	3.4848 (1.72 to 7.07)	0.0005	5.1109 (2.29 to 11.41)	<0.0001
Female	1		1	

apical lesions was observed in 63 roots of teeth endodontically treated, and in one case of untreated teeth. In the premolar group, there were 43 roots with endodontic treatment, and 12 without endodontic treatment, with apical lesions in 27 and in one case, respectively. No extrusion of filling material was observed involving the root apexes.

The analyses of the present study's images were performed using the InVivoDental by Anatomage (Copyright 2005© Anatomage, USA, All Rights Reserved). The images were interpreted initially by doing a comprehensive observation of the area and selecting the area of higher proximity of the tooth apex with the maxillary sinus. Then three parasagittal sections with 1-mm interval difference between them were assessed for the data obtaining. A standard sequence for analysis was established, starting with the second premolar, then the first molar, and, finally, the second molar of one quadrant, and thus successively to the other quadrant.

Results

The vertical relationships between the roots of the posterior upper teeth and the sinus floor exhibited a predominance of type I among the second premolars, whereas, in the first and second molars, there was a predominance of type II and III, respectively (Table 1).

The logistic regression indicated that there were no significant relationships between the thickening of the sinus mucosa and the distance from the root apexes to the sinus floors (p=0.0901), presence of endodontic treatment (p=0.1257), and type of tooth (Premolars p=0.9083; First Molars p=0.5827; Second Molars p=0.4984).

The prevalence of teeth treated with thickening was 40.9% for second premolars, 40.7% for first molars, and 36% for second molars. Among the untreated teeth, the prevalence was 22.6% for second premolars, 28.7% for first molars, and 26.5% for second molars (Table 2).

The variables age (p=0.0442), presence of periapical lesions (p=0.0109), and sex (p<0.0001) were associated with the presence of sinus thickening, with odds ratios of 1.03, 2.99, and 5.11, respectively (Table 3).

Discussion

The proximity of the posterior upper teeth with the sinus floor was investigated in the present study indicating a possible pattern in which the more posterior the teeth are, the greater the probability of intimate contact of the roots with the maxillary sinus. The variables correlated with maxillary sinus thickening were analyzed, too, highlighting a predilection for male patients. The CBCT was used to assess the proximity of the posterior teeth roots to the maxillary sinus. This method provides dentists with more accurate information about the maxillary sinus than radiographic images, which exhibit low accuracy and tend to overestimate the roots' protrusion into the sinus (17-19). Our study's root classification was proposed by Kwak et al. (16) and cited in several studies (7, 20, 21).

Pagin et al. (22) found that the prevalence of root protrusion within the maxillary sinuses was 2.8% for premolars, 11.9% for first molars, and 23.2% for second molars, corroborating the findings of the present study, i.e., in second premolars, protrusion (type III) was observed in 5.6% of cases, for first molars in 12.4% (type III), and second molars in 34.2% (type III) of cases. Likewise, Kang et al. (23) demonstrated that the presence of protrusion of the roots into the sinuses was greater when they went towards the posterior region (first premolars=1.5%; second premolars=14.48%; first molars=40.5%; and second molars=44.77%). In the present study, most second premolars (57.7%) were classified as type I, most first molars (48.4%) as type II, and most second molars (34.2%) as type III. These results are in line with those found in other studies (21) that observed prevalence of type I in second premolars (52.9%) and type II in first and second molars (54.6 and 61.7%, respectively). These results show the proximity of the root apexes to the maxillary sinus. Because of that, the endodontist needs to avoid over instrumentation of root canals, extrusion of filling material and debris (24), which can lead to consequent communication with the maxillary sinus, and sinus mucosa inflammation, which can also occur in cases of inadvertent injection or extrusion of irrigants (25).

As for the presence of sinus thickening, we found a prevalence of 27.8%, which is a low percentage compared to those of other studies (26, 27). This fact can be explained by the difference in ethnicity and the methods used. Gürhan et al. (28) have shown that mucosal thickening is associated with periapical lesions in almost 50% of all mucosal thickening cases. This factor demonstrates the importance of collaboration among endodontists and otolaryngologists to provide successful treatment and prevent maxillary sinusitis's recurrence.

Nascimento et al. correlated the maxillary sinus's thickening with inadequate endodontic treatment, resulting in the variable's lack of significance (27). In our study, the presence of endodontic treatment was assessed in a general and independent way, regardless of being appropriate or inappropriate. The variable was also non-significant, which can be explained by the fact that although the quality of the treatment was not assessed, in this study, the majority of root canal treatment (55.20%) did not present the presence of periapical lesions associated with them (confirmed by Chi-Square test), demonstrating signs of successful treatments.

The distance from the apex of the sinus and the tooth type did not influence the sinus's thickening. Teeth with periapical lesions were more likely to exhibit thickening of the maxillary sinus, in line with other studies' results (2, 7, 29, 30). These factors demonstrate that the presence of thickening is not related to the proximity of the sinus or the type of tooth but the presence of infection.

These findings demonstrate the endodontist's need for attention in the treatment and follow up of upper posterior teeth since if they develop or have periapical lesions, they can be a risk factor to the development of maxillary thickening (31,

32). Age was also a factor correlated with thickening, showing that the older the patients are, the greater the chance of thickening, corroborating with previous studies (33, 34).
This factor can be explained by the literature, which shows that older patients are more susceptible to dental problems, such as cavities, periodontitis, and missing teeth (11), increasing the maxillary thickening probability.
Male patients were more likely to exhibit thickening of the maxillary sinus when compared to female patients, a fact also observed by later studies (27, 35, 36). Although the study did not collect habits data and is not the study's objective, based on previous studies, smoking rates among men vary between can 43.3% to 65.3% against 9.3% to 15.5% between women (37) since there is a positive association between sinusitis and cigarette smoking (38, 39) and this study have not excluded smokers patients, the authors of this study believe it can be an explanation to the results found in this research. Another possible explanation is that men have more dental disease that irritates the maxillary sinus membrane (28).

Conclusions

It is important to emphasize that only one observer analyzed the slices by only one reading which can be a limitation of our study. The second molars, followed by the first molars and then the second premolars, are the teeth that have shown the higher proximity with the maxillary sinus. A correlation between age, sex, and presence of periradicular lesions with thickening of the sinus mucosa was found.

Clinical Relevance

Identifying the proximity of the root apexes of posterior maxillary teeth to the maxillary sinus is clinically important before endodontic treatments. Recognizing the factors that can increase the chance of thickening of the maxillary sinus mucosa can potentially lead to more successful treatments.

Conflict of Interest

None.

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