Article published online: 2023-11-23

Evaluation of Association between Maxillary Posterior Teeth Periapical Pathologies and Maxillary Sinus Mucosal Changes—A Cone-Beam Computed Tomography (CBCT) Study

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Indian J Radiol Imaging 2024;34:246–253.

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Abstract

Introduction Odontogenic infections are one of the common causes of maxillary sinusitis. With the close proximity of the roots of maxillary posterior teeth to the sinus floor, the infection may spread into the sinus causing sinus mucosal thickening. This study aims to evaluate the association between maxillary posterior teeth periapical pathologies and maxillary sinus mucosal changes using cone-beam computed tomography (CBCT) images.

Methods One-hundred six maxillary posterior teeth with periapical lesions were included in this study and were assessed using CBCT images by two maxillofacial radiologists. The proximity of the roots to the sinus floor, the proximity of the top edge of the periapical lesion to the sinus floor, and the sinus mucosal changes associated with the periapical lesions were studied. The size of the periapical lesion was measured and scored using CBCT periapical index. Mucosal thickening more than 2 mm was considered pathological and the type, pattern, and severity of mucosal thickening were assessed. Data were analyzed using chi-squared tests at a level of significance set at *p*-value less than 0.05.

Results Among the 106 teeth with periapical lesions, 99 teeth (93.4%) revealed the presence of maxillary sinus mucosal thickening. The prevalence of mucosal thickening increased significantly with the presence of cortical bone destruction, the close proximity of the root, and the periapical lesion to the sinus floor. The generalized type of mucosal thickening was more prevalent with larger periapical lesions and a significant increase in the severity of the thickening was observed closer spatial relationship of the root to the sinus floor.

Conclusion Periapical pathologies of maxillary posterior teeth often cause sinus mucosal thickening. The early diagnosis and management of these pathologies will be helpful in preventing the spread of infection into the maxillary sinus.

Keywords
- cone-beam computed tomography
- maxillary sinus
- mucosal thickening
- periapical pathologies

article published online
November 23, 2023

DOI https://doi.org/10.1055/s-0043-1777013.
ISSN 0971-3026.

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Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

Maxillary sinusitis is a globally prevalent disease that is mainly caused by allergies or respiratory infections.[1] The maxillary sinus (MS) floor extends from the first premolar to the maxillary tuberosity but may reach the zygomatic bone, the alveolar ridge after extractions, and the anterior canine. Due to the juxtaposition of the roots of maxillary posterior teeth to the sinus floor, a substantial proportion of maxillary sinusitis cases has an odontogenic origin.[2,3] The periapical infection has been shown to affect the sinus mucosa even without perforation of the cortical sinus floor, with the infection spreading via bone marrow, blood vessels, and lymphatics to the sinus. Bacteria, their toxins, and products of pulpal necrosis may spread to the MS, and lead to inflammation.[4–6]

Normal sinus mucosa cannot be visualized on radiographs, but, when infected or due to allergy, it may become thicker and, therefore, visible on images. Radiographic findings are important in the diagnosis of odontogenic sinusitis. Two-dimensional intraoral periapical (IOPA) radiograph can provide limited data on the location and extent of periapical lesions of maxillary posterior teeth due to the superimposition of adjacent structures such as palatal root or zygomatic bone.

Computerized tomography (CT)/multidetector CT is the gold standard diagnostic technique for sinus pathologies; however, it may not be adequate for diagnosing maxillary sinusitis of odontogenic origin because of its low spatial resolution.[7–9] Cone-beam computed tomographic (CBCT) imaging is beneficial for assessing the relationship between the tooth morphology and the adjacent anatomic structures and is a valuable technique for the evaluation of periapical lesions.[10] Therefore, CBCT that has a much lower radiation dose and higher spatial resolution may be helpful for diagnosing maxillary sinusitis of odontogenic origin. Hence, in this study, we aim to evaluate the association between maxillary posterior teeth periapical pathologies and MS mucosal changes using CBCT images.[8]

Materials and Methods

This study was conducted among patients who visited the outpatient Department of Oral Medicine and Radiology, The Oxford Dental College, Bangalore. The patients who clinically presented with deep dental caries involving the pulp of maxillary posterior teeth with pain and with or without associated symptoms of maxillary sinusitis (headache, heaviness of head-on postural variations, nasal congestions) were included in this study. One-hundred six teeth of patients who clinically presented with deep dental caries involving the pulp of maxillary posterior teeth were enrolled in the study.

Before conducting the study, ethical clearance was obtained from the institutional ethical board of The Oxford Dental College, and written informed consent was obtained from the patients. After a detailed history including any history of sinusitis, the intraoral examination was performed. The teeth with deep dental caries involving the pulp were subjected to IOPA radiography. IOPA was performed on a conventional intraoral machine at 70 kVp, 10 mA for 0.8 seconds. The radiograph was obtained using the bisecting angle technique with Kodak E-speed films and was manually processed. The IOPA radiograph was evaluated for any periapical pathology and the position of the roots of the maxillary posterior teeth to the sinus. The patients presented with periapical pathologies were subjected to CBCT examination.

CBCT imaging of the teeth was performed using Kodak Carestream CS 9300 system machine set at 90 kVp, 10 mA, and 11.26 seconds with a typical voxel size of 90 µm. CS three-dimensional imaging software was used for reconstruction and assessment. All the images were assessed by two radiologists with varying levels of experience in reading CBCT images. The images were assessed for the size of the periapical lesion, the presence of cortical bone expansion or destruction, MS mucosal changes, the position of the root of the tooth to the sinus floor, and the position of the upper edge of the lesion to the sinus.

Before the measurements, the slice thickness of all the sections (sagittal, coronal, and axial) of the CBCT image was adjusted to 75 µm. The periapical lesion size was measured in all three sections (mesiodistal, bucco-palatal, and diagonal) on the CBCT image using the working tool on the CS software. The sagittal section was used for measuring the mesiodistal width of the lesion, and the coronal and axial sections were used for bucco-palatal and diagonal measurements, respectively (►**Fig. 1**). For the multirooted tooth, the lesion on all the roots was measured and the highest measurement was considered. The periapical lesion was scored based on the CBCT-PAI (periapical index).[11] The presence or absence of cortical bone expansion and destruction is inspected in all the three sections(coronal, sagital, and axial) as shown in ►**Fig. 2**.

	CBCT-PAI
Score	Quantitative bone alterations in mineral structures
0	Intact periapical bone structures
1	Diameter of periapical radiolucency >0.5–1 mm
2	Diameter of periapical radiolucency >1–2 mm
3	Diameter of periapical radiolucency >2–4 mm
4	Diameter of periapical radiolucency >4–8 mm
5	Diameter of periapical radiolucency >8 mm Score (*n*)
+E	Expansion of periapical cortical bone Score (*n*)
+D	Destruction of periapical cortical bone

The *anatomical relationship* between maxillary teeth and the sinus was determined for all the teeth (►**Fig. 3**) and classified as[10]:

Type I: There was a space between the roots and the sinus floor,
Type II: At least one root of the tooth was in contact with the sinus floor,
Type III: At least one root of the tooth entered the sinus floor.

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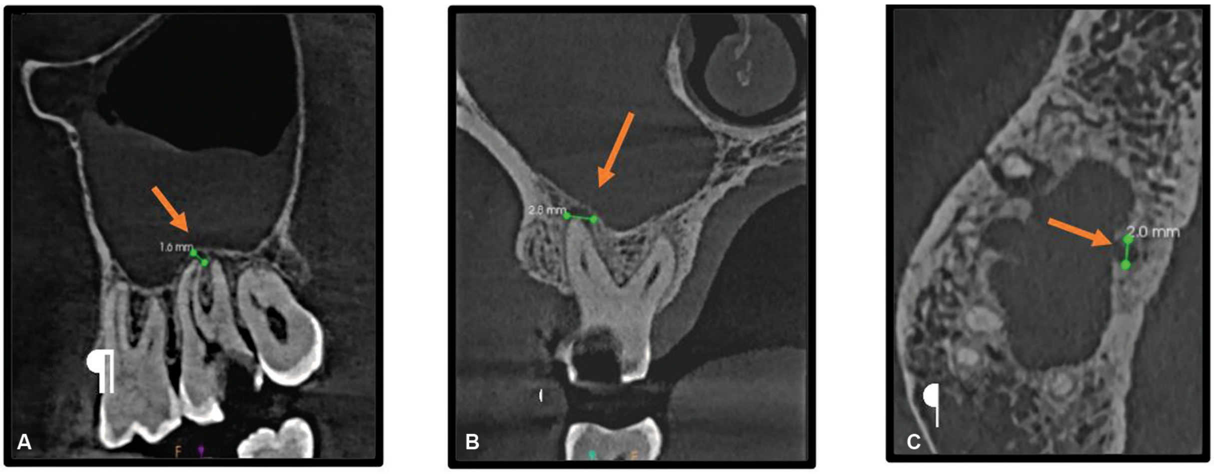

Fig. 1 Measurement of the size of periapical lesion on cone-beam computed tomography (CBCT) image. The arrows show (**A**) Mesiodistal measurement on sagittal section. (**B**) Buccolingual measurement on coronal section of CBCT. (**C**) Measurement of depth of periapical lesion on axial section.

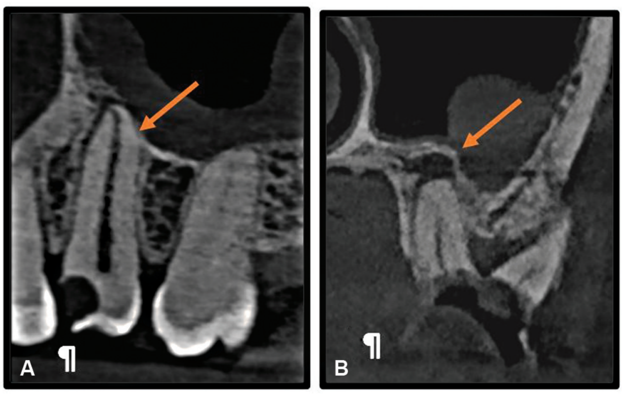

Fig. 2 (**A**) Sagittal section showing cortical bone destruction. (**B**) Arrow shows coronal section showing cortical bone expansion.

The relationship between the size of the upper edge of the lesion and the sinus floor was measured in all the teeth (►**Fig. 4**) and recorded as:

Type I: The lesion extending into the sinus
Type II: The lesion was juxtaposed to the MS floor (0 mm)
Type III: Distance from the top edge of the lesion to the sinus floor more than 0 to less than 2mm
Type IV: Distance from the top edge of the lesion to the sinus floor more than or equal to 2mm

The mucosal changes of the sinus were assessed in all three sections of the CBCT images.

The presence or absence of mucosal thickening (area without cortical bone and with soft tissue density, thickness >3 mm, parallel to sinus bone wall)

(i) Mucosal thickening was **classified** as:

Based on the type: Generalized and localized
Based on the pattern: Flat and polypoid (►**Fig. 5**)

(ii) The mucosal thickening was measured in the coronal section (►**Fig. 6**) of the image and classified based on severity[10]:

Grade I: Normal (0–2 mm)
Grade II: Moderate (2–10 mm)
Grade III: Severe ($\geq$ 10 mm).

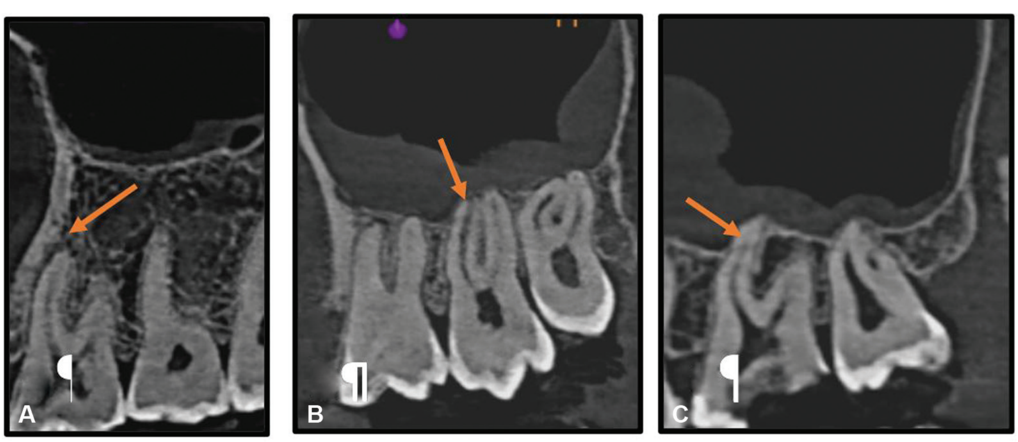

Fig. 3 Cone-beam computed tomography images showing the different anatomic relationships between maxillary sinuses and teeth. (**A**) Type 1—Presence of space between the roots and the sinus floor. (**B**) Type 2—at least one root of the tooth in contact with the sinus floor. (**C**) Arrow shows type 3—At least one root of the tooth into the sinus.

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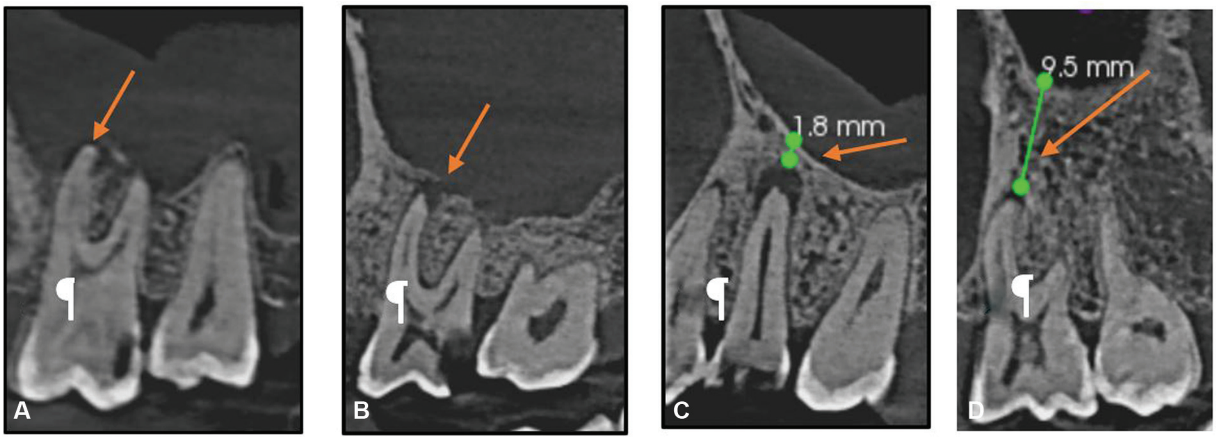

Fig. 4 Cone-beam computed tomography images showing the distance from the top edge of the lesion to the floor of sinus. (**A**) Type 1—The lesion extending into the sinus. (**B**) Type 2—The lesion was juxtaposed to the maxillary sinus floor (0 mm). (**C**) Type 3—Distance from the top edge of lesion (the arrow shows) to sinus floor more than 0 to less than 2 mm. (**D**) Type 4—Distance from the top edge of lesion to sinus floor more than or equal to 2mm.

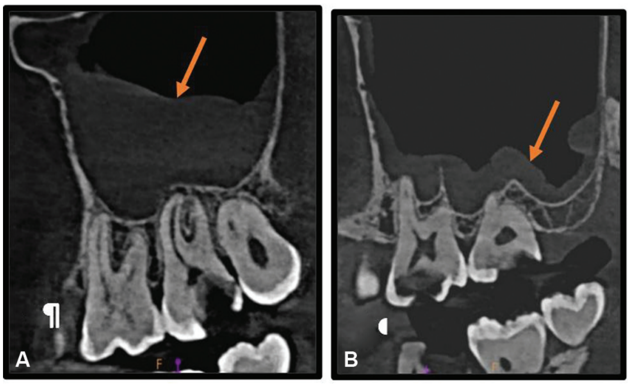

Fig. 5 Type of mucosal thickening. The arrows show: (**A**) Sagittal section showing the flat type of mucosal thickening. (**B**) Sagittal section showing the polypoidal type of mucosal thickening.

Fig. 6 Coronal section showing the measurement of mucosal thickening.

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. IBM Corp., Armonk, New York, United States was used to perform statistical analyses. Chi-squared test was used to compare the cortical expansion and destruction, CBCT-PAI scores, anatomical position of the tooth root to the sinus floor, and distance from the tooth edge of the lesion to the sinus floor based on mucosal thickening. Similarly, chi-squared test was also used to estimate the association between study variables and different characteristics of sinus mucosal thickening among study subjects. The level of significance was set at *p*-value less than 0.05.

Results

The study involved 19 premolars (18%) (8 on the right side and 11 on the left side) and 87 molars (82%) (38 on the right side and 49 on the left side). In this study, 19.8% of participants were having a history of sinusitis and 99 teeth (93.4%) revealed the presence of MS mucosal thickening. All the teeth with cortical bone destruction (100%) and 26 teeth (78.8%) without cortical bone destruction showed the presence of sinus mucosal thickening. This difference was statistically significant (►**Table 1**).

All the teeth with type II and type III anatomical position of the root to the sinus floor showed the presence of sinus mucosal thickening (100%), whereas 75% (30) teeth with type I anatomical position showed sinus mucosal thickening. The difference was statistically significant with *p*-value less than 0.001(►**Table 1**).

In this study, all the teeth (29 teeth) with a distance from the top edge of the lesion to the sinus floor of score 1 showed mucosal thickening (100%), whereas of score 2, score 3 and score 4 showed 96.4%, 80%, and 71.4% of mucosal thickening, respectively. Our study revealed that the shorter the distance of the periapical lesion to the sinus, the higher chances of mucosal thickening and the difference was statistically significant $p = 0.005$ (►**Table 1**).

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Table 1 Comparison of CBCT-PAI, cortical expansion and destruction, anatomical position of root to sinus floor, and distance from top edge of lesion to sinus floor with sinus MT using chi-squared test

Variable	Category	MT present		MT absent		*p*-Value
		n	%	*n*	%	
CBCT-PAI	PAI 2	16	88.9	2	11.1	0.40
	PAI 3	66	93.0	5	7.0	
	PAI 4	17	100.0	0	0.0	
Cortical expansion	Present	15	88.2	2	11.8	0.35
	Absent	84	94.4	5	5.6	
Cortical destruction	Present	73	100.0	0	0.0	<0.001*
	Absent	26	78.8	7	21.2	
Anatomical position	Type I	21	75	7	25	<0.001*
	Type II	38	100.0	0	0.0	
	Type III	40	100.0	0	0.0	
Distance	Score 1	29	100.0	0		0.005*
	Score 2	53	96.4	2	3.6	
	Score 3	12	80	3	20	
	Score 4	5	71.4	2	28.6	

Abbreviations: CBCT-PAI, cone-beam computed tomography-periapical index; MT, mucosal thickening.
*Statistically significant.

Table 2 Characteristics of mucosal thickening of maxillary sinus among study subjects

Variable	Category	*n*	%
Nature of thickening	NA	7	6.6
	Generalized	33	31.1
	Localized	66	62.3
Pattern	Normal	7	6.6
	Flat	69	65.1
	Polypoid	30	28.3
Grade	Normal	7	6.6
	Moderate	62	58.5
	Severe	37	34.9

Abbreviation: NA, not available.

Out of 99 teeth showing the presence of MS mucosal thickening, 33 (31.1%) teeth showed generalized mucosal thickening and 66 (62.3%) showed localized. The pattern of thickening was flat in 69 (65.1%) teeth and polypoidal in 30 (28.3%) teeth. The grade of thickening was moderate in 62 (58.5%) teeth and severe in 37 (34.9%) teeth (►**Table 2**).

In this study, 69.7% of patients with PAI score 3 showed moderate mucosal thickening as compared with 82.4% of patients with PAI score 4 that showed severe grade of thickening. This difference was statistically significant with *p*-value less than 0.001 (►**Table 3**). The anatomical position of root type II shows a significantly higher proportion of moderate mucosal thickening (70.8%) than the anatomical position of root type III with a severe grade of thickening (56.7%), which was statistically significant with *p*-value equal to 0.03 (►**Fig. 7**).

The interobserver reliability of different study variables between two observers showed almost perfect agreement with Kappa value ranging from 0.91 to 1.00 that was

Table 3 Association between CBCT-PAI and characteristics of mucosal thickening using chi-squared test

	Type				
CBCT-PAI	Generalized		Localized		*p*-Value
	n	%	*n*	%	
PAI 2	6	37.5	10	62.5	0.001[a]
PAI 3	15	22.7	51	77.3	
PAI 4	12	70.6	5	29.4	
	Pattern				
	Flat		Polypoid		
PAI 2	11	68.8	5	31.3	0.87
PAI 3	47	71.2	19	28.8	
PAI 4	11	64.7	6	35.3	
	Severity/grade				
	Moderate		Severe		
PAI 2	13	81.3%	3	18.8%	<0.001[a]
PAI 3	46	69.7%	20	30.3%	
PAI 4	3	17.6%	14	82.4%	

Abbreviation: CBCT-PAI, cone-beam computed tomography-periapical index.
[a]Statistically significant.

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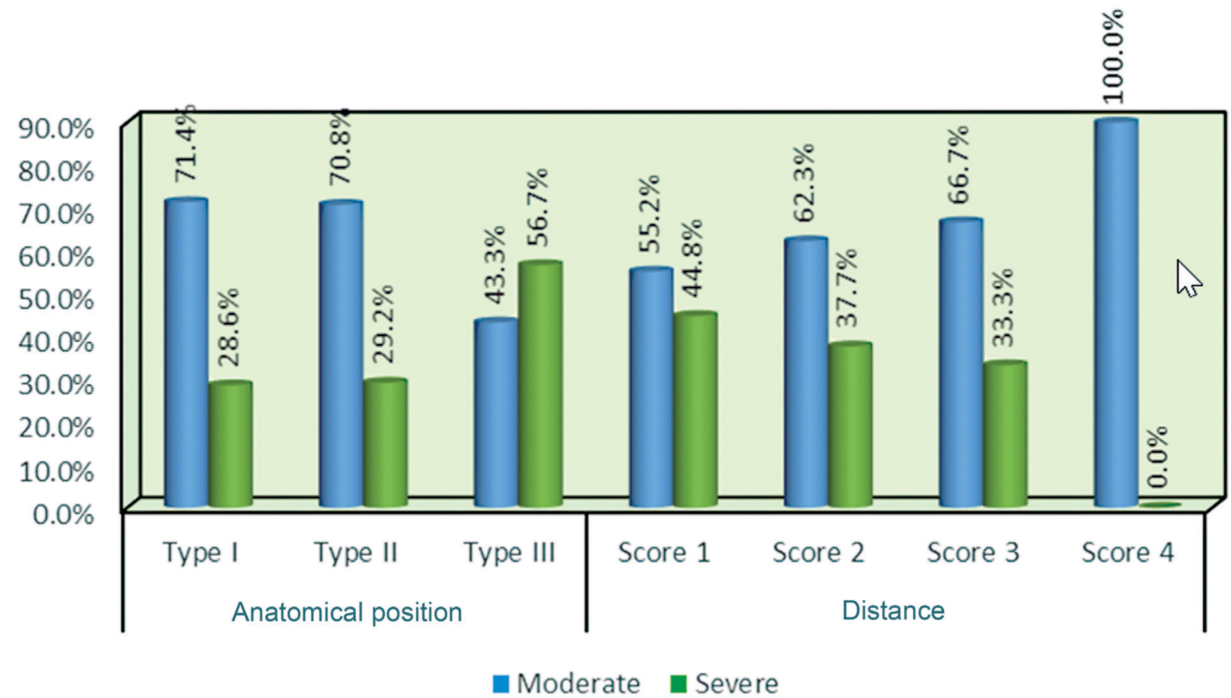

Fig. 7 Association between anatomical position of tooth root and distance of top edge of the lesion to the sinus floor and grade of sinus mucosal thickening.

statistically significant at *p*-value equal to 0.001 and *p*-value less than 0.001(►**Table 4**).

Cohen's Kappa Value

≤ 0 indicates No agreement;
0.01–0.20 indicates none to slight agreement
0.21–0.40 indicates fair agreement
0.41–0.60 indicates moderate agreement
0.61–0.80 indicates substantial agreement and
0.81–1.00 indicates almost perfect agreement.

Discussion

In this study, a greater proportion (93.4%) of study participants revealed the presence of MS mucosal thickening, and only 6.6% did not show any sinus mucosal changes. These findings were in accordance with a study done by Shanbhag et al,[1] wherein a total of 243 patients, 60% prevalence of mucosal thickening was noted and the teeth with periapical lesions were 9.75 times more likely to be associated with mucosal thickening than those without. In another study by Lu et al[12] on 88 teeth with maxillary posterior teeth apical periodontitis, more than 80% had MS mucosal thickening.

The symptoms of maxillary sinusitis include headache, heaviness of head-on postural variation, nasal congestion, rhinorrhea, and/or foul odor and taste.[13] In this study, 19.8% (21) of participants gave a positive history of sinusitis among which 95% (20) showed the presence of mucosal thickening. In most of these cases, localized mucosal thickening (52%) was observed, whereas generalized thickening was observed in 43% of cases with a history of sinusitis The infections of upper premolars and molars (both periapical or periodontal) may spread beyond the supporting dental tissues into the MS and cause sinusitis. Multiple conditions, including periapical infection, root canal treatment, and close relationship between maxillary teeth and sinus, may have a precursor effect on the occurrence of mucosal thickening in the MS. After pulp necrosis, collagenase, lysosomal enzymes, and toxins produced by the bacteria promote bacterial invasion and tissue breakdown in the periapical bone. Thus, infections and their by-products from the teeth may spread to the MS and become a potential cause of sinus mucosal irritation.[10] In this study, 100% of participants with a PAI score of 4 showed thickening of the sinus mucosa and 93% with a score of PAI 3 showed mucosal thickening which revealed an increase in the prevalence of mucosal thickening with an increase in the size of periapical lesion; however, the difference was not statistically significant. Several authors have correlated the size of the periapical lesion and mucosal thickening. Lu et al[12] and Vallo et al[14] reported that the prevalence of MS mucosal thickening increased with the size of the lesion. Similarly, a study by Goller-Bulut et al[15] on 205 patients who had 410 exposed MS reported that the mucosal thickening increased as the degree of apical periodontitis increased. Cortical bone expansion and destruction are the two variables in the CBCT-PAI. In our study, 88.2% of teeth with cortical bone expansion showed the presence of mucosal thickening, whereas 100% of teeth with cortical bone destruction were showing mucosal thickening. From the literature, the palatal root of the maxillary first molar often penetrated into the sinus, the mesiobuccal root of the second molar juxtaposed to the sinus, and the premolar roots seldom protruded into the sinus cavity. This relationship may result in various risks, especially for certain surgical procedures, such as tooth extraction and implant placement, or during endodontic or

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Table 4 Interobserver reliability analysis for different study variables between two observers using Kappa statistics

Variables	Category	Observer-1		Observer-2		Kappa value	*p*-Value
		n	%	*n*	%		
Mucosal thickening	Present	99	93.4	99	93.4	1.00	<0.001*
	Absent	7	6.6	7	6.6		
Cortical expansion	Present	17	16.0	15	14.2	0.96	<0.001*
	Absent	89	84.0	91	85.8		
Cortical destruction	Present	73	68.9	73	68.9	1.00	<0.001*
	Absent	23	31.1	23	31.1		
PAI	PAI 2	18	17.0	17	16.0	0.98	<0.001*
	PAI 3	71	67.0	72	68.0		
	PAI 4	17	16.0	17	16.0		
Anatomical positioning	Type I	28	26.4	28	26.4	0.96	<0.001*
	Type II	48	45.3	46	43.4		
	Type III	30	28.3	32	30.2		
Distance	Score 1	29	27.4	29	27.4	0.93	<0.001*
	Score 2	55	51.9	53	50.0		
	Score 3	15	14.2	18	17.0		
	Score 4	7	6.5	6	5.6		
Nature of thickening	NA	7	6.6	7	6.6	0.96	<0.001*
	Generalized	33	31.1	30	28.3		
	Localized	66	62.3	69	65.1		
Pattern	Normal	7	6.6	7	6.6	1.00	<0.001*
	Flat	69	65.1	69	65.1		
	Polypoid	30	28.3	30	28.3		
Grade	Normal	7	6.6	7	6.6	0.91	0.001*
	Moderate	62	58.5	55	51.9		
	Severe	37	34.9	44	41.5		

Abbreviations: NA, not available; PAI, periapical index.
*Statistically significant.

orthodontic treatments.[16] In our study, 100% of participants with type II and III anatomical positions of root to sinus showed mucosal thickening. On the contrary, a retrospective study done by Aksoy and Orhan[9] concluded that the solely anatomic relationship seems not to affect the MS mucosal thickening.

The close proximity of the periapical lesions and the MS may be a potential factor in the thickening of the sinus mucosa. In this study, the top edge of the periapical lesion extending into the sinus floor (100%) showed the highest number of abnormalities, suggesting an effect of proximity of the periapical lesion on the sinus mucosa. This was in accordance with the study done by Nunes et al,[2] which revealed that the highest number of abnormalities were found in association with the teeth whose most apical lesion edge was sub adjacent to the floor of MS (distance = 0) In contradiction, a study done by Rege et al[17] on 1,113 patients did not find any significant relation with the proximity of the periapical lesion to the sinus mucosa. Similarly, a study by Lu et al[12] on 508 exposed sinuses did not reveal any association between periapical lesion proximity and sinus abnormality.

Mucosal thickening can be classified as generalized and localized, flat and polypoid,[18,19] and moderate and severe. In our study, a higher proportion (62.3%) of localized sinus mucosal thickening was present among the study participants. This study also showed a variation in the prevalence of the type of mucosal thickening by the size of the lesion. A higher proportion of PAI scores II and III (62.5% & 77.3%) showed localized mucosal thickening, whereas PAI score IV showed generalized thickening of mucosa (70.6%).

Polypoid lesions represent mucous retention cysts or mucosal polyps and appear as dome-shaped radiopaque thickenings of the sinus mucosa.[20] A majority of the sinuses with thickened mucosa presented with a flat type of thickening (65.1%), whereas polypoid thickening was observed less frequently (28.3%) in this study. This finding was consistent with the study done by Shanbhag et al[1] and Gürhan et al.[21]

Most sinuses with thickened mucosa showed a moderate grade of thickening (58.5%), whereas a severe grade of thickening was observed less frequently (37%) in this study. The severity prevalence showed variation by the lesion's size

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and the anatomical position of root to sinus. In this study, age did not influence the grade of mucosal thickening. A higher proportion of moderate mucosal thickening was seen in anatomical position type I and II (71.4 and 70.8%, respectively), whereas severe thickening was observed higher in the type III anatomical position of the root, which indicates that the severity of the thickening of the sinus mucosa increases with an increase in the size of the lesion and close proximity of the root to the sinus floor.

The effect of the size of the periapical lesion and the spatial relationship of the root and the top edge of the periapical lesion to the sinus floor was evaluated in our study. However, the periodontal status of the teeth was not considered that could cause sinus mucosal changes and this study also lacks control groups.

Conclusion

The findings of our study revealed a high prevalence of sinus mucosal thickening (93.4%, $n = 93$) associated with periapical lesions. The prevalence of mucosal thickening increased with the size of the lesion and with the presence of cortical bone destruction. A significant increase in mucosal thickening incidence was found with the close proximity of the root to the sinus floor. The generalized type of mucosal thickening was more prevalent with larger periapical lesions and a significant increase in the severity of the thickening was observed with an increase in the size of the lesion and closer spatial relationship of the root to the sinus floor. This study also revealed the presence of sinus mucosal thickening in the absence of symptoms of sinusitis.

The diagnosis and management of odontogenic maxillary sinusitis often present challenges. Oral and maxillofacial radiologists play an important role in assessing the periapical lesions and their association with sinus mucosal changes that often help otolaryngologists in providing effective treatment. The early diagnosis and management of the periapical lesions of maxillary posterior teeth can be helpful in preventing the spread of infection into the MS.

Funding
None.

Conflict of Interest
None declared.

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