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ORIGINAL ARTICLE

Association between the dimensions of the maxillary sinus membrane and molar periodontal status: A retrospective CBCT study

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Abstract

Background: The information of the association between residual alveolar bone height and mucosal thickening is sparse. This study aimed to explore the effect of maxillary molar periodontal status on sinus mucosal thickening using cone-beam computed tomography (CBCT).

Methods: One hundred ninety-four CBCT images were evaluated for the following parameters: age, sex, alveolar bone loss, maximum mucosal thickness (maxMT), minimum residual alveolar bone height (minRABH), and vertical infrabony pockets. The presence of mucosal thickening (maxMT > 2 mm) of the maxillary sinus was recorded. The parameters that could influence the dimensions of the maxillary sinus membrane were assessed. The data were analyzed using logistic regression, and multivariate linear regression with the significant level at $\alpha = 0.05$.

Results: Mucosal thickening was present in 32% of the analyzed CBCT images and increased in frequency as the periodontal status of the corresponding molar progressed from mild (2.6%) to moderate (14.9%) to severe (75.5%). Mucosal thickness was significantly increased in cases of moderate (odds ratio = 5.73, $P < 0.05$) and severe (odds ratio = 82.06, $P < 0.001$) alveolar bone loss. Multivariate linear regression revealed that alveolar bone loss and minRABH had a statistically significant influence on maxMT ($P < 0.05$).

Conclusions: Alveolar bone loss and minRABH were significantly associated with mucosal thickening of the maxillary sinus.

KEYWORDS

cone-beam computed tomography, molars, mucosal thickening, periodontitis

1 | INTRODUCTION

Initially caused by microbial biofilm, periodontal disease is a chronic infection that leads to calculus formation, local infection, severe resorption of alveolar bone, tooth mobility in the late stage, and exfoliation.[1] The maxillary molars are easily subject to periodontal infection because of their complicated root morphology characterized by concavity of the root surface and furcation.[2] Furthermore, infection in the maxillary posterior region may affect the maxillary sinuses because of the close anatomical proximity of the maxillary molars and the maxillary sinus floor;

such infection may cause thickening of the maxillary sinus mucosa.[3,4]

Odontogenic infection is one of the major causes of maxillary sinusitis with an incidence rate between 10% and 12%.[5] The most common finding is mucosal thickening in patients with odontogenic sinusitis. Several studies have shown that mucosal thickness greater than 2 mm is present in most patients with maxillary sinusitis.[6,7] Therefore, sinus mucosal thickening of more than 2 mm is a significant indicator of maxillary sinusitis and is considered to be a pathologic result.[8] Radiographically, thickened mucosa appears as a non-corticated radiopaque band, paralleling the internal cortical bone wall of the sinus.[8]

Maxillary molars affected with severe periodontitis may be unsalvageable and are commonly extracted according to implant restoration treatment planning. Because of significant bone loss around molars affected by severe periodontal disease, sinus augmentation surgery has become a widely used and predictable procedure for increasing bone height to the level required for implant placement.[9] However, perforation of the maxillary sinus mucosa is one of the most common complications of the sinus augmentation procedure.[10] Adjacent sinus mucosal thickness is an important factor related to sinus membrane perforation during the sinus augmentation procedure.[11] Therefore, during the treatment planning stage prior to surgery, it is crucial to assess the sinus condition and mucosal thickness.

Many studies have shown that maxillary sinus mucosal thickening is associated with periodontitis.[12-14] Phothikhun et al.[14] measured a three-fold increase in the likelihood of mucosal thickening in the presence of severe periodontitis. Goller-Bulut et al.[12] reported a significant correlation between maxillary sinus mucosal thickening and alveolar bone loss. The majority of previous studies have focused only on the relationship between maxillary sinus mucosal thickening and alveolar bone loss instead of on residual alveolar bone height.[15]

Although conventional computed tomography examination was considered the gold standard for sinus visualization and diagnostic procedures, cone-beam computed tomography (CBCT) recently has been used widely for imaging studies of dental and maxillofacial regions.[16] CBCT imaging offers lower radiation dosage, shorter scanning time, higher image resolution, and lower cost compared to traditional CT.[17] CBCT was proven to be reliable for the evaluation of structures in the maxillary sinus, as well as periapical and periodontal alveolar bone changes.[18-20] The objectives of this study were to apply CBCT imaging to investigate the relationship between the dimensions of the maxillary sinus membrane and corresponding molar periodontal status, and to explore the possible parameters influencing mucosal thickness. The hypothesis was that alveolar bone loss and minimum residual alveolar bone height would lead to mucous membrane thickening.

2 | MATERIALS AND METHODS

2.1 | CBCT images selection

The study protocol was conducted in full accordance with the ethical principles established in the World Medical Association Declaration of Helsinki of 1975 as revised in 2000, and approved by the Ethical Committee of the Peking University School of Stomatology (Approval Number: PKUSSIRB-201946078). Oral informed consents were obtained from all participants and the extracted data in the present study was anonymized. All CBCT images from patients with clinically diagnosed periodontal disease and needed to receive periodontal treatment subsequently were retrospectively collected within the time period between February 2014 and October 2017 in the Department of Periodontology, Peking University School and Hospital of Stomatology. The following inclusion criteria were applied for image selection: (1) Good quality image taken using New Tom VG CBCT (Aperio Services, Italy) at 110 kVp and 13.8 mA with an exposure time of 18 seconds. The voxel sizes of the images were 0.15 mm with 12 cm × 8 cm field of view and 0.2 mm slice thickness; (2) The occlusal plane being parallel to the floor. Exclusion criteria were as follows: (1) history of maxillary sinusitis; (2) subjects with nasal congestion, runny nose, fever, and any other nasal symptoms within the last 3 months; (3) dental caries, periapical lesions, cracked lesions, existed dental fillings, or root canal treatment in the posterior maxillary teeth; (4) missing premolar or molar teeth (except for the third molar) in the maxilla; (5) pregnancy and lactation; (6) seasonal or pollen allergy reaction history; (7) asthma or COPD cases; (8) Maxillary mucosal cyst or bony septum; (9) sign of acute sinusitis, such as an air-fluid level or complete opacification; (10) history of periodontal surgery in the maxillary posterior region; and (11) smoker.

2.2 | CBCT image analysis and assessment

Five hundred seventy CBCT images were examined and 194 CBCT images (50% males and 50% females) were included. The main reasons for exclusion were dental caries, periapical lesions, existed dental fillings or root canal treatment in the posterior maxillary teeth beneath the maxillary sinus. Patients were classified into three age groups as follows: 19 to 35 years, 35 to 44 years, and ≥44 years.

Only one sinus per CBCT image—the one with the most severely affected molar with regard to bone loss was selected to analyze. Images were reconstructed and processed in picture archiving and communication systems (PACS) image

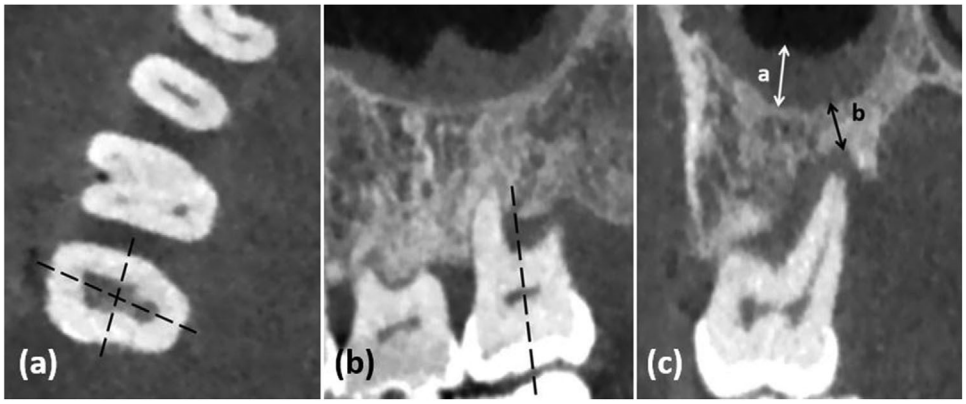

FIGURE 1 Image reconstruction and processing. (**A**) Axial view. (**B**) Sagittal view. (**C**) Coronal view showing measurements of a: maximum mucosal thickness (maxMT) and b: minimum residual alveolar bone height (minRABH)

system (Version 11.0, Carestream Health, Canada) as follows: (1) the maxillary molar with the most severe bone resorption was selected and reference lines passing through the midpoint of the pulp cavity at the level of maxillary molar medullary cavity bottom were determined in the axial view; (2) in the sagittal view, a reference line was assigned to pass the long axis of the molar; (3) morphology of the maxillary sinus mucosa and corresponding molar were examined from mesial side to distal side of the molar at the coronal view to determine and measure the maximum mucosal thickness and the minimum vertical distance from the most apical alveolar bone of the molar to the bottom of the maxillary sinus, Figure 1.

The measurements included:

1. Maximum mucosal thickness (maxMT): Thickness of sinus mucosa categorized as either normal (maxMT $\leq$ 2 mm) or thickened (maxMT $>$ 2 mm),[21] Figure 1. Mucosal thickening was classified to localized or generalized.[22]
2. Minimum residual alveolar bone height (minRABH), defined as the shortest vertical distance from the most apical alveolar bone of the molar to the bony edge of the maxillary sinus. The minRABH was graded as follows: <4 mm, 4 to 10 mm, and ≥10 mm.[23]
3. Vertical infrabony pockets were classified as follows: Type 1, no pocket; Type 2, infrabony pocket depth ≥3 mm, with the defect within the middle one-third of the root; Type 3, the bony defect reached to the apical one-third of the root.[6]
4. Alveolar bone loss was assessed from the sagittal and coronal views at four sides (mesial, distal, buccal, and lingual) of each tooth and was calculated as a percentage of normal alveolar bone height. Normal alveolar bone height was determined as the distance from 2 mm below the cementoenamel junction to the tip of the root.[24] The maximal percentage of alveolar bone loss was classified as follows: 1. Mild, <25% bone loss; 2. Moderate, from 25% to 50% bone loss; and 3. Severe, >50% bone loss.[25]

All images were measured by two calibrated investigator (BZ and GY.) who were trained by an experienced radiologist. To assess Intraexaminer and interexaminer reliability, 20 randomly selected CBCT images were measured twice on two different days (interval ≥14 days). The intraclass correlation coefficient was determined to be 0.995 for maxMT and 0.994 for minRABH, Cohen's kappa values were 0.912 for alveolar bone loss and 0.917 for vertical infrabony pockets. The error between two measurements from one observer was 0.3 ± 0.3 mm for maxMT and 0.4 ± 0.3 mm for minRABH. The interclass correlation coefficient was 0.984 for maxMT and 0.985 for minRABH. The error between the two observers was 0.4 ± 0.4 mm for maxMT and 0.4 ± 0.4 mm for minRABH. Cohen's kappa values were 0.829 for alveolar bone loss and 0.837 for vertical infrabony pockets, hence, the measurement error was determined to be negligible.

2.3 | Statistical analyses

Consistency of the two measurements was evaluated by the intra-group correlation coefficient method and Cohen's kappa test; the data were described by frequency, mean ± SD, and range. Binary logistic regression analysis was used to determine the impact of each independent variable on mucosal thickening. Multivariate linear regression analysis was used to determine potential influencing variables on mucosal thickness. The data were shown as the odds ratios (ORs) with 95% confidence intervals (CIs). A P value <0.05 was considered statistically significant. All computations were conducted using SPSS version 22.0 (SPSS Inc., Chicago, IL).

3 | RESULTS

CBCT images of 194 maxillary sinuses and 194 teeth with periodontal disease from 194 individuals (97 males and 97 females, aged 19 to 63 years; mean age: 37.5 ± 10.6 years)

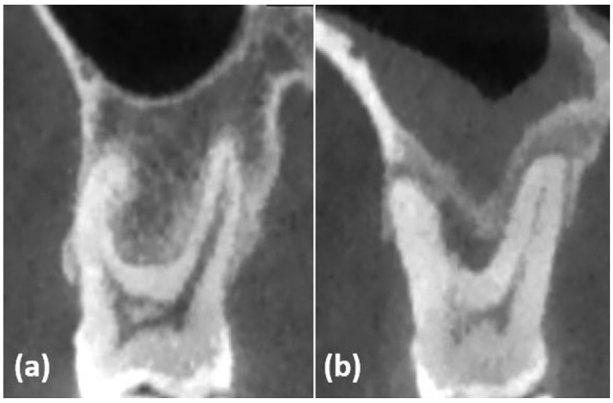

FIGURE 2 Coronal views of the maxillary sinus. (**A**) Normal sinus mucosa. (**B**) Thickened sinus mucosa

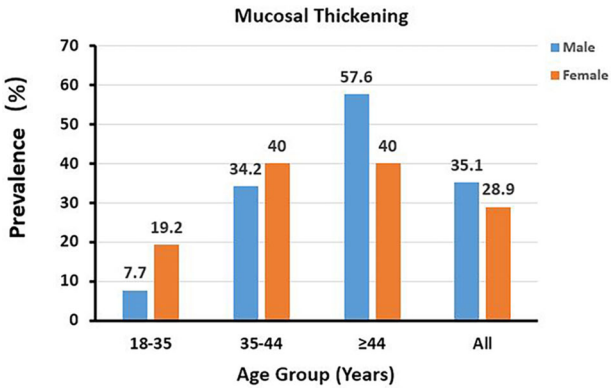

FIGURE 3 Prevalence of mucosal thickening of the maxillary sinus according to age and sex

were reviewed. CBCT images of maxillary sinuses with normal and thickened mucosa are shown in Figure 2. Images with mucosal thickening were observed in 62 sinuses (32%). In sinuses with mucosal thickening, the average mucosal thickness was 4.2 ± 2.1 mm (range: 2.0 to 9.8 mm), and they were generalized in all cases. The prevalence of mucosal thickening was higher in male patients than in female patients (male patients, 35.1%; female patients, 28.9%) and the prevalence of mucosal thickening was higher for the older age group (≥44 years), Figure 3.

The distribution of maxillary sinus CBCT images according to different parameters is shown in Table 1. The percentage of sinuses with mild, moderate, and severe alveolar bone loss of the corresponding molars was 39.7%, 24.2%, and 36.1%, respectively. The prevalence of maxillary sinus mucosal thickening was 2.6%, 14.9%, and 75.5% in patients with mild, moderate, and severe alveolar bone loss, respectively.

Binary logistic regression analysis revealed that the likelihood of mucosal thickening increased commensurate with the status of periodontal bone loss (moderate: odds ratio = 5.73, 95% CI: 1.01 to 32.44, $P < 0.05$; severe: odds ratio = 82.06, 95% CI: 13.36 to 504.18, $P < 0.001$). Sinus floor with minRABH <4 mm was eight times more likely to display mucosal thickening (odds ratio = 8.09, $P = 0.025$), Table 2. Results of testing under a multivariate linear regression model determined that alveolar bone loss and minRABH had a statistically significant influence on maximum mucosal thickness ($P < 0.05$), Table 3.

TABLE 1 Association between parameters and mucosal thickening of the maxillary sinuses

Parameters	*N* (%)	Mucosal thickening	
		Presence *n* (%)	Absence *n* (%)
Age			
19–35	78 (40.2)	12 (15.4)	66 (84.6)
35–44	63 (32.5)	23 (36.5)	40 (63.5)
≥44	53 (27.3)	27 (50.9)	26 (49.1)
Sex			
Male	97 (50.0)	34 (35.1)	63 (64.9)
Female	97 (50.0)	28 (28.9)	69 (71.1)
Molar site			
First molar	110 (56.7)	41 (37.3)	69 (62.9)
Second molar	84 (43.3)	21 (25.0)	63 (75.0)
Alveolar bone loss			
Mild	77 (39.7)	2 (2.6)	75 (97.4)
Moderate	47 (24.2)	7 (14.9)	40 (85.1)
Severe	70 (36.1)	53 (75.7)	17 (24.3)
minRABH			
<4 mm	55 (28.4)	39 (70.9)	16 (29.1)
4–10 mm	102 (52.6)	21 (20.6)	81 (79.4)
≥10 mm	37 (19.1)	2 (5.4)	35 (94.6)
Vertical infrabony pockets			
Type 1	98 (50.5)	23 (23.5)	75 (76.5)
Type 2	77 (39.7)	22 (28.6)	55 (71.4)
Type 3	19 (9.8)	17 (89.5)	2 (10.5)

minRABH, minimum residual alveolar bone height.
Type 1. No pocket; Type 2. Infrabony pocket depth ≥3 mm, the defect was within the middle one-third of the root; Type 3. The defect reached to the apical one-third of the root.

4 | DISCUSSION

The aims of this study were to investigate the association between the dimensions of the maxillary sinus membrane and corresponding molar periodontal status as well as other variables. Analysis of measurements of mucosa thickening revealed statistically significant associations with alveolar bone loss and minRABH.

The prevalence of maxillary sinus mucosal thickening in our study was 2.6%, 14.9%, and 75.5% for patients with mild,

TABLE 2 Odds ratio (OR) and 95% confidence interval (CI) for the risk of mucosal thickening of the maxillary sinus

	Mucosal thickening		
Parameters	**OR**	**95% CI**	***P* value**[a]
Age			
35–44 versus 19–35	0.64	0.18–2.28	0.488
≥44 versus 19–35	0.56	0.15–2.09	0.383
Sex			
Male versus female	1.90	0.71–5.05	0.200
Molar site			
First molar versus second molar	0.533	0.17–1.63	0.270
Alveolar bone loss			
Moderate versus mild	5.73	1.01–32.44	0.048[b]
Severe versus mild	82.06	13.36–504.18	<0.001[b]
minRABH			
<4 mm versus ≥10 mm	8.09	1.31–50.10	0.025[b]
4–10 mm versus ≥10 mm	2.72	0.49–15.06	0.251
Vertical infrabony pockets			
Type 2 versus Type 1	1.09	0.40–2.95	0.861
Type 3 versus Type 1	3.06	0.54–17.34	0.207

Type 1. No pocket; Type 2. Infrabony pocket depth ≥ 3 mm, the defect was within the middle one-third of the root; Type 3. The defect reached to the apical one third of the root.

minRABH, minimum residual alveolar bone height.

[a]Binary logistic regression analysis.

[b]Statistically significant differences at $P < 0.05$.

TABLE 3 Multivariate analysis of potential relevant parameters on maximum mucosal thickening (maxMT)

	maxMT		
Parameters	**Coefficient**	***T* value**	***P* value**[b]
Age	0.001	−0.362	0.718
Sex	−0.032	−0.846	0.399
Molar site	0.004	1.012	0.313
Alveolar bone loss	0.176	5.469	<0.001[b]
minRABH	−0.238	−3.810	<0.001[b]
Vertical infrabony pockets	0.046	1.496	0.136

[a]Multivariate linear regression analysis.

[b]Statistically significant differences at $P < 0.05$.

maxMT, maximum mucosal thickness; minRABH, minimum residual alveolar bone height.

moderate, and severe alveolar bone loss, respectively. These values are consistent with previously published reports indicating the contribution of periodontal disease to mucosal thickening.[6,14,26] Phothikhun et al.[14] investigated mucosal abnormalities of the maxillary sinus and determined a threefold increase in the likelihood of mucosal thickening with severe periodontitis cases and an odds ratio of 3.02. In the present study, patients with severe alveolar bone loss had significantly higher risk, with an odds ratio of 82.06 for mucosal thickening compared with patients demonstrating mild alveolar bone loss. This large odds ratio difference may be related to differences in the criteria used to define mucosal thickening between studies. This study adopted maximum health mucosal thickness with no >2 mm instead of 1 mm for samples with periodontal disease.[7,21,27] The maxillary molar with the most severe bone resorption were selected for the assessment and their adjacent mucosal thickness were measured to determine the thickening changes. In the current study, mucosal thickening were generalized in all cases, which may be because of the generalized periodontal disease condition, in accordance with previous study.[22]

The average mucosal thickness of the thickened sinus mucosa was 4.2 ± 2.1 mm, similar to a previous study that found the average mucosal thickness was 5.98 mm.[12] A possible reason for the lower thickness values obtained in the present study is the strict exclusion of any maxillary sinus mucosal thickening caused by pathological conditions such as mucosa cysts and other odontogenic reasons (except periodontitis).[28] In the current study, results of mucosal thickening assessment revealed no statistically significant difference between males and females (male patients, 35.1% and female patients, 28.9%). However, a previous study by Vallo et al. indicated a frequency of mucosal thickening of 18% for male patients and of 8% for female patients, and a study by Ren et al. showed frequencies of mucosal thickening of 58.3% for males and of 42.5% for females.[6,26] These dissimilarities may be because of differing patient selection criteria among studies. In the present study, all subjects needed to receive periodontal treatment subsequently and smokers were excluded. In contrast, Vallo et al. analyzed comprehensive recruits consisting of both healthy and pathological oral conditions by panoramic radiography, and Ren et al. included smokers in their study. According to previous studies, a positive association between sinusitis and cigarette smoking have been demonstrated.[29,30]

The prevalence of periodontal disease was shown to have a positive correlation with age, which may also contribute to the risk of mucosal thickening.[31] Results of this study revealed that the prevalence of mucosal thickening increased with age. Mucosal thickening occurred more frequently in the older age group (≥44 years old), which is consistent with previous reports.[6,14]

The maxillary molars are usually separated from the maxillary sinus floor by a dense cortical bone with a variable thickness, but sometimes they are separated only by the mucoperiosteum.[32] Odontogenic infection may reach the sinus via direct diffusion through porous maxillary bone or through vascular and lymphatic systems, affecting the sinus mucosa.[33] Consequently, the closer the infected molar is to the maxillary sinus, the more likely the infection will spread into the maxillary sinus. The shortest distance from the most apical alveolar bone of the infected molar to the osseous edge of

the maxillary sinus, described as the minRABH, is one of the important parameters affecting maxillary sinus mucosal thickening. Bornstein et al. proposed a possible thickening of bone apical to periapical lesion and thickening of mucus membrane of the maxillary sinus because of the inflammatory reaction.[34] However, no other research has explored the relationship between the minimum residual alveolar bone thickness and changes in mucosal thickening. The current study found that the maximal thickness of the maxillary sinus mucosa was negatively correlated with the minimum residual alveolar bone height ($r = -0.238$, $P < 0.001$). When the minimum residual alveolar bone height was measured at less than 4 mm, 70.9% of maxillary sinuses displayed significant changes in mucosal thickness.

Because of limitations in equipment and ethics, this study can only explore the relationship between periodontitis and mucosal thickening using CBCT imaging studies retrospectively. It was a limitation that there was no true control group—posterior teeth/patients without signs of periodontal pathology. Clinical examination and histopathological and microbiological studies on thickened maxillary sinus mucosa are expected to provide an improved understanding of the mechanisms of mucosal change and thickening. Although CBCT imaging offers lower radiation dosage, shorter scanning time, higher image resolution, and lower cost compared to traditional CT, there was still an indubitable difference between CT measurement of maxillary sinus mucosal thickness and true mucosal thickness.

5 | CONCLUSIONS

Within the limitations of this study, the two key parameters associated with changes in mucosal thickening are the degree of alveolar bone loss and the minRABH adjacent to the infected molar. The possibility of mucosal thickening is increased if minRABH is <4 mm. Early detection and intervention of periodontal diseases to improve minRABH beneath the sinus are highly recommended for clinical implication.

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AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: Wenjie Hu, Bo Zhang, and Yiping Wei. Performed the experiments: Bo Zhang, Yiping Wei, and Gang Yang. Analyzed the data: Bo Zhang, Yiping Wei, Jie Cao, and Tao Xu. Manuscript preparation: Bo Zhang, Yiping Wei, and Min Zhen. Manuscript revisions: Bo Zhang, Yiping Wei, Wenjie Hu, and Kwok-Hung Chung.

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