Original paper

Retrospective analysis of the relationship between Schneiderian membrane thickness and periodontitis severity using cone beam computed tomography (CBCT)

Sathyavalli Veluri[1,A–D], Sruthima Naga Venkata Satya Gottumukkala[1,A,C–F], Gautami Penmetsa[1,C,E], Ramesh Santosh Venkata Konathala[1,C,E], Geetanjali Darna[1,B,C], Mohan Kumar Pasupuleti[1,C,D], Satyanarayana Raju Mantena[2,C,E]

[1] Department of Periodontics and Implantology, Vishnu Dental College, Bhimavaram, India
[2] Department of Prosthodontics and Implantology, Vishnu Dental College, Bhimavaram, India

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl*. 2025;62(1):65–72

Address for correspondence
Sruthima Naga Venkata Satya Gottumukkala
E-mail: sruthima@vdc.edu.in

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
None declared

Received on December 22, 2021
Reviewed on February 19, 2022
Accepted on March 4, 2022

Published online on February 18, 2025

Abstract

Background. Due to the close proximity of maxillary molars to the maxillary sinuses, the bacteria at the root tip region of the sinus can quickly access the maxillary sinus. This can result in maxillary sinus mucosal inflammation and thickening of the Schneiderian membrane.

Objectives. The aim of the study was to determine the thickness of the maxillary sinus membrane and to correlate this thickening with the severity of periodontitis using cone beam computed tomography (CBCT) analysis.

Material and methods. The CBCT data of 231 patients, with a mean age of 40.59 years, was assessed to evaluate the mucosal thickness (MT), the remaining height of the alveolar bone (RHAB), the type of periodontitis, the type of defect, and the extent of bone loss.

Results. When RHAB was ≤4 mm, mucosal thickening was evident in the majority of the images (128 (89.5%); $p = 0.000$). The multivariate logistic regression analysis demonstrated that the probability of MT increase is proportionate to the severity of periodontal disease (odds ratio (*OR*): 9.179, confidence interval (*CI*): 2.831–29.761; $p = 0.000$). First molars were most frequently associated with mucosal thickening (*OR*: 1.050, *CI*: 0.311–3.541; $p = 0.009$). Additionally, mucosal thickening was more evident on the sinus floor in cases where RHAB was less than 4 mm.

Conclusions. The increase in MT is associated with the severity and distribution of periodontal disease, particularly with horizontal defects.

Keywords: cone beam computed tomography, maxillary sinus, periodontitis, alveolar bone loss, Schneiderian membrane

Cite as
Veluri S, Gottumukkala SNVS, Penmetsa G, et al. Retrospective analysis of the relationship between Schneiderian membrane thickness and periodontitis severity using cone beam computed tomography (CBCT). *Dent Med Probl.* 2025;62(1):65–72. doi:10.17219/dmp/147105

DOI
10.17219/dmp/147105

Highlights

- The study revealed a correlation between the thickness of the maxillary sinus membrane and the severity of periodontitis.
- Mucosal thickening was more evident for RHAB ≤ 4 mm, indicating a link between alveolar bone loss and sinus membrane thickening.
- First molars were most frequently associated with membrane thickening, highlighting the importance of monitoring these areas in patients with periodontitis.

Introduction

Periodontal disease is a chronic infectious condition that leads to the loss of supporting alveolar bone and mobility of the teeth. If left untreated, it eventually results in tooth exfoliation. Due to the intricate root architecture, which includes the contour of the root surface, and furcation, maxillary molars and premolars are more prone to periodontal infection.[1] Furthermore, the roots of maxillary posterior teeth are in the vicinity of the maxillary sinus floor, and infections in this region may affect the maxillary sinuses, leading to maxillary sinus mucosal thickening.

The etiology of maxillary sinusitis can be classified as either odontogenic or nasogenic, with the former accounting for 10–12% of all cases.[2] Odontogenic maxillary sinusitis is the result of the pathological interaction of periodontal structures with the maxillary sinus membrane. As maxillary molars are in close proximity to the maxillary sinuses, the bacteria at the root tip region of the sinus can rapidly become infected. Bacteria gain access to the maxillary sinus through the porous alveolar bone, causing an inflammatory reaction.

Various odontogenic conditions violate the physiological position of the sinus membrane, leading to its increased thickness. These conditions include periapical abscess, periodontal disease, dental trauma, implant placement, and tooth extraction. Periodontitis is an inflammatory condition that can contribute to odontogenic maxillary sinusitis, leading to Schneiderian membrane thickening.[3]

In dentistry, the maxillary sinus has been visualized via panoramic radiography, Water's view and intraoral radiography. However, the intricate design of the oral and maxillofacial area makes it challenging to visualize key anatomical traits due to superimposition.[4,5] The thickness of the maxillary sinus membrane is difficult to evaluate with the use of routine radiographic techniques. Since its introduction in dentistry and maxillofacial imaging, cone beam computed tomography (CBCT) analysis has enabled the diagnosis of sensitive structures in multiplanar reconstructions.[6] This technique also allows for an extremely high diagnostic level, such as perfect matching with photographic acquisitions of the patient's face, and thus enables surgical programming to achieve even more adequate aesthetics. The ability to perform precise cephalometric analyses for orthodontic and orthognathic surgery purposes represents a significant turning point in the orthodontic diagnosis.[7,8] Cone beam computed tomography can be used to visualize the paranasal sinuses, peri-apical and periodontal tissues due to its reduced radiation dosage and isotropic volume resolution. This imaging technique is the gold standard for sinus diagnosis, allowing for the examination of both hard tissue components in numerous sections of sinus in various planes.[9]

There are conflicting reports regarding the influence of periodontal disease on maxillary sinus thickness. Few studies have shown an association between increased mucosal thickness (MT) and periapical and periodontal infections.[1,2]

Objectives

Although numerous studies have addressed the association between periodontal disease and MT, the literature lacks sufficient evidence to make any definitive statements. Therefore, further research is necessary to compare the severity of periodontal disease with MT. The present study aimed to assess the thickness of the Schneiderian membrane and correlate the results with the periodontal disease status using CBCT.

Material and methods

Study protocol and data collection

The Institutional Ethics Committee of Vishnu Dental College, Bhimavaram, India, approved the study protocol, which adhered to the 2013 Declaration of Helsinki. The CBCT data from periodontally healthy individuals and those with clinical signs of periodontitis was collected in the Department of Periodontics and Implantology of Vishnu Dental College between January 2020 and August 2021. The demographic and clinical data of the participants was obtained from the electronic medical record management system. The three-dimensional (3D) images in the maxillary premolar and molar regions were reconstructed using 3D visualization and evaluated with the SCANORA® Imaging System, v. 5.2 (SOREDEX, Tuusula, Finland).

Sample size

A total sample size of 231 was calculated using G*Power software, v. 3.10 (https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower). The calculations were based on MT in patients with periodontitis as the primary outcome, with an effect size of 0.04, a 95% confidence level, and a margin of error of 57%.

Patient selection

The Cranex® 3D imagining system (SOREDEX) was used to obtain good quality images of the maxillary posterior sextants. The images were taken at 90 kVp and 8 mA with an exposure length of 10 s. The pictures had 0.13-mm voxels, a field of view of 6 cm × 4 cm, and a slice thickness of 0 mm.

Participants with signs or a history of sinusitis, common cold, rise in the body temperature, or symptoms of a viral or respiratory infection in the previous 3 months, as well as pregnant or lactating women, smokers, and individuals with a history of allergic rhinitis, bronchitis or chronic pulmonary diseases, and radiographic signs of sinusitis or sinus lesions were excluded from the study. Additionally, individuals with carious teeth, endodontically involved teeth, cracked teeth, existing dental restorations, premolars and molars requiring endodontic treatment, missing maxillary posterior teeth, the presence of any mucosal cysts or septa, and those who underwent periodontal therapy were excluded.

CBCT image analysis

A total of 459 CBCT images were assessed, out of which 231 images met the selection criteria and were included in the study. The main reasons for exclusion were periapical lesions, the presence of dental caries, existing dental fillings or root canal treatment in posterior maxillary teeth, radiographic signs of sinusitis, or sinus lesions. The participants were categorized into 3 age groups based on the availability of CBCT images within the study period (i.e., from January 2020 to August 2021), as follows: 20–35 years; 36–50 years; and >50 years. All images of maxillary molars and premolars were examined in the coronal view to assess MT and the remaining height of the alveolar bone (RHAB) with the use of 3D imaging equipment. The type of defects and the extent of bone loss were examined in a panoramic view.

Maximum MT measurement

The floor of the maxillary sinus was assessed for MT in the coronal view, allowing the complete length of the thickened mucosa to be examined. The thickness was measured from the sinus floor to the highest border of the mucosa in millimeters. The thickness of the sinus mucosa was described as normal if maximum MT was ≤2 mm, and as thickened if maximum MT was >2 mm.[10]

Remaining height of the alveolar bone

The RHAB is defined as the shortest distance between the terminal alveolar bone of the tooth root and the crest of the maxillary sinus. Based on a study by Yoo et al., RHAB was divided into 3 categories: ≤4 mm; 5–9 mm; and ≥10 mm.[11] The measurement was obtained by scrolling over the scan of maxillary posterior teeth in the coronal and sagittal planes. An orientation line was created on the CBCT picture to represent RHAB.

Estimation of the type of defects and the extent of bone loss

The defects were determined in the panoramic view by scrolling over the scans (Fig. 1), and subsequently categorized into horizontal and vertical based on the relation of the crest of the alveolar bone to the imaginary line joining the cementoenamel junction of the adjacent teeth. The extent of bone loss was graded as mild (<15%), moderate (15–33%) or severe (>33%), according to the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions by the American Academy of Periodontology (AAP).[12]

Fig. 1. Panoramic radiograph illustrating the extent of bone loss

Evaluation of periodontitis

Patients exhibiting generalized chronic periodontitis with probing pocket depth (PPD) of 4 mm and clinical attachment level (CAL) of 1–2 mm were categorized as

healthy (mild periodontitis). Those with PPD of 6–7 mm and CAL of 3–4 mm were classified as moderate periodontitis group, and individuals with PPD ≥ 8 mm and CAL ≥ 5 mm were diagnosed with severe periodontitis. The study included first and second premolars as well as first and second molars from each quadrant of the mouth.

Statistical analysis

The intragroup comparison was conducted using the χ^2 test. The Pearson correlation coefficient was used to investigate the correlation between MT and the severity of bone loss. The evaluation of the effect of variables on MT was conducted using the multivariate linear regression analysis. The odds ratio (*OR*) with a 95% confidence interval (*CI*) was used to present the data. A *p*-value of less than 0.05 was considered statistically significant. The IBM SPSS Statistics for Windows software, v. 25.0 (IBM Corp., Armonk, USA), was used to analyze the data.

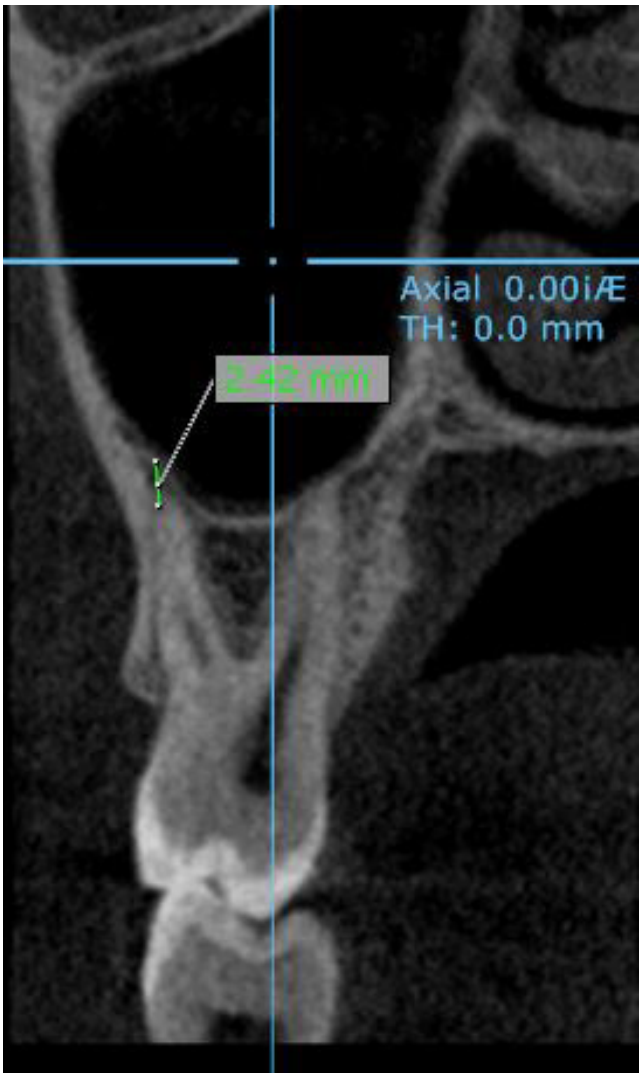

Fig. 2. Coronal view of the maxillary sinus with normal sinus mucosa
TH – thickness.

Results

A total of 231 CBCT images of maxillary sinuses from both periodontally healthy and clinically diagnosed individuals with periodontal disease (121 males and 110 females, aged 20–63 years; mean age: 40.59 years) were evaluated. Patients above the age of 40 were found to have a higher prevalence of mucosal thickening. The CBCT images of normal and thickened mucosa in the maxillary sinuses are presented in Figures 2 and 3. Generalized mucosal thickening was observed in 179 sinuses (77.5%; $p = 0.000$). The average MT in sinuses with mucosal thickening was 4.24 mm (range: 2–14 mm). A higher frequency of mucosal thickening was observed in female patients compared to male patients (80.9% compared to 74.4%, respectively) (Table 1).

In cases where the alveolar bone height was less than or equal to 4 mm, mucosal thickening was observed in the majority of the images (128 (89.5%); $p = 0.000$). The maxillary sinus membrane was thickened in 68 CBCT images, characterized by significant alveolar bone loss (87.2%; $p = 0.020$). Mucosal thickening was considerable in horizontal defects in 121 images, i.e., 82.9% ($p = 0.001$).

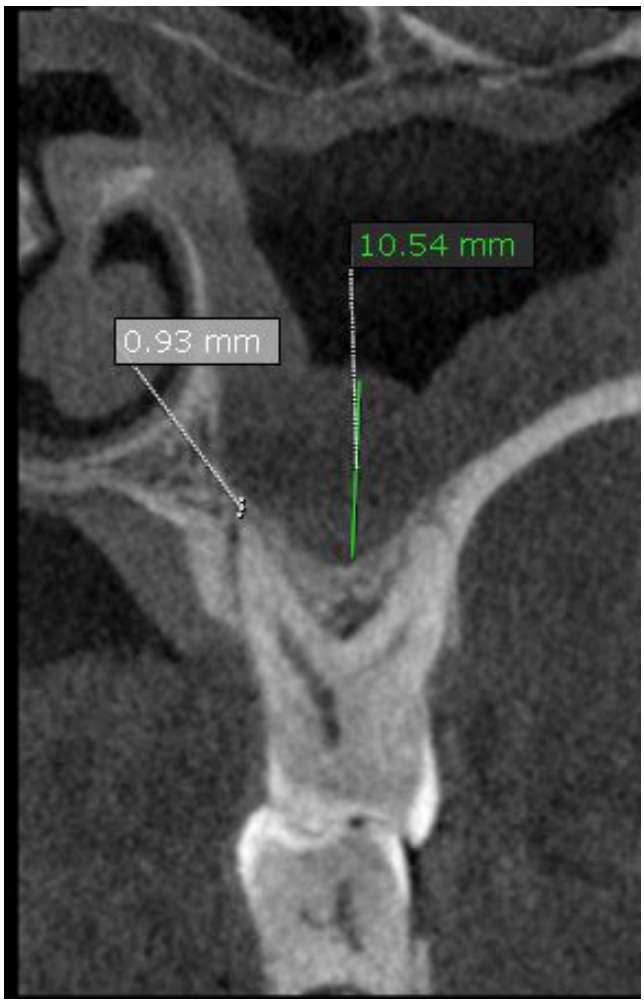

Fig. 3. Coronal view of the maxillary sinus with thickened sinus mucosa

Table 1. Association between demographic variables and mucosal thickening of the Schneiderian membrane

Variable		Mucosal thickening		*OR*	*CI*
		absent *n* (%)	present *n* (%)		
Age [years]	20–35	23 (25.6)	67 (74.4)	1.747	0.604–5.056
	36–50	11 (14.1)	67 (85.9)		
	>50	18 (28.6)	45 (71.4)	1.742	0.582–5.207
Gender	male	31 (25.6)	90 (74.4)	0.435	0.175–1.081
	female	21 (19.1)	89 (80.9)		

OR – odds ratio; *CI* – confidence interval.

The thickening was most prevalent in second molars (83.3%), followed by first molars (82.6%), second premolars (75.8%) and first premolars (56.7%) (p = 0.019) (Table 2). In patients with mucosal thickening, a mean bone loss of 4.765 ±2.100 mm was observed (p = 0.034) (Table 3).

The multivariate linear logistic regression analysis revealed that the prevalence of mucosal thickening increased in response to the presence of periodontal disease (*OR:* 9.179, *CI*: 2.831–29.761; p = 0.000). Mucosal thickening was more evident on the sinus floor in cases where RHAB was <4 mm (average RHAB: 2.746 ±1.659 mm) (*OR* = 1.292, *CI*: 0.00–0.041; p = 0.000). First molars were most frequently associated with mucosal thickening (*OR* = 1.050, *CI*: 0.311–3.541; p = 0.009) (Table 2). The mean RHAB of 2.746 ±1.659 mm was found to be statistically significant (p = 0.023) in patients with MT ≥ 4.24 mm.

Table 3. Mean age, remaining height of the alveolar bone (RHAB) and bone loss of the study participants in relation to mucosal thickening of the Schneiderian membrane

Variable	Mucosal thickening	*M*	*SD*	T value	*p*-value
Age [years]	present	40.630	10.324	0.164	0.870
	absent	40.290	12.983		
RHAB [mm]	present	2.746	1.659	–2.296	0.023*
	absent	3.480	1.636		
Bone loss [mm]	present	4.765	2.100	2.134	0.034*
	absent	3.903	2.039		

* statistically significant (p < 0.05, independent t-test); *M* – mean; *SD* – standard deviation.

Discussion

The causes of mucosal thickening include periodontal disease, apical periodontitis, other odontogenic diseases, and tooth extraction.[13–16] The degree of thickening serves as a crucial factor in determining the likelihood of infection being caused by a tooth. A paucity of studies correlated the severity of periodontitis with maxillary sinus membrane thickening.[1,2,17] Furthermore, none of the early research included any clinical exams. The purpose of this study was to investigate the relationship between the thickness of the Schneiderian membrane and the periodontal condition of the corresponding maxillary posterior teeth, the severity of periodontal disease, the extent and type of bone loss, and RHAB.

Table 2. Association between periodontal parameters and mucosal thickening of the Schneiderian membrane

Parameter		Mucosal thickening		*p*-value	*OR*	*CI*	*p*-value
		absent *n* (%)	present *n* (%)				
Alveolar bone loss	absent/minimal	29 (32.6)	60 (67.4)	0.020*	–	–	0.486
	moderate	13 (20.3)	51 (79.7)		0.498	0.070–3.541	
	severe	10 (12.8)	68 (87.2)		1.249	0.167–9.349	
Defect	horizontal	25 (17.1)	121 (82.9)	0.001*	–	–	0.884
	vertical	27 (31.8)	58 (68.2)		0.880	0.157–4.936	
Minimum residual bone height [mm]	0–4	15 (10.5)	128 (89.5)	0.000**	–	–	0.000**
	4–10	37 (49.3)	38 (50.7)		0.104	0.041–0.261	
	>10	0 (0.0)	13 (100.0)		1.292	0.000–0.041	
Group	healthy	30 (52.6)	27 (47.4)	0.000**	–	–	0.000**
	periodontitis	22 (12.6)	152 (87.4)		9.179	2.831-29.761	
Teeth	first molars	12 (17.4)	57 (82.6)	0.019*	–	–	0.009*
	first premolars	13 (43.3)	17 (56.7)		0.180	0.050–0.651	
	second molars	11 (16.7)	55 (83.3)		1.050	0.311–3.541	
	second premolars	16 (24.2)	50 (75.8)		0.993	0.299–3.299	

* statistically significant (p < 0.05); ** highly statistically significant (p < 0.001, χ^2 test).

Mucosal thickening was observed in 89.3%, 50.3% and 100% of participants with mild, moderate and severe bone loss, respectively. The results of this study are consistent with those of previous research.[1] The *OR* of severe alveolar bone loss was 1.249 (*CI*: 0.167–9.349; $p = 0.486$), suggesting that the risk of mucosal thickening increases with the severity of periodontal disease. The outcomes of the present study concur with those of a previous investigation by Phothikhun et al., who found a significant increase, i.e., threefold, in patients with severe alveolar bone loss compared to patients with mild bone loss.[18]

In the present study, mucosal thickening was more prevalent in females compared to males (80.9% vs. 74.4%, respectively). However, this difference was not statistically significant, presumably due to the inconsistency in patient selection. This finding is in contrast to the results of the study by Vallo et al., where thickening was more common in males, and was twice as prevalent in males than in females (18% vs. 8%, respectively).[19] The authors examined the occurrence of oral infections as a whole, rather than categorizing them.[19] Similar contradictory results in relation to age were reported in a study of a Chinese population, with a prevalence of 58.3% in males and 42.5% in females.[20]

The dimensions of the maxillary sinus vary depending on numerous factors, including the presence or absence of teeth, the duration of edentulousness, and periapical infection as the age of the individual increases.[21] In our sample size, with an average age of 40.59 years, mucosal thickening was found to be most prevalent in patients aged 36–50 years. The present findings are comparable with those reported by Ren et al., who described an increase in the prevalence of mucosal thickening in patients aged 26–40 years and a decline thereafter.[20] This observation could be attributed to the higher prevalence of aggressive forms of periodontitis in younger individuals, which could have led to increased thickening. However, these findings contradict those reported by Shanbhag et al., who observed a statistically significant increase in mucosal thickening in individuals older than 60.[16]

The mean MT was 4.24 mm, with a distribution of localized cases to molars in 55.1% and generalized cases in 87.0% of the patients. However, Zhang et al. reported an average MT of 4.2 ±2.1 mm with generalized mucosal thickening in all cases.[1] The potential reasons for this discrepancy could be the strict exclusion of any pathological cysts, tumors or overgrowths in our study.[1]

In the present study, mucosal thickening was more prevalent in horizontal defects (82.9%) than in vertical defects (68.2%). This finding contradicts the results reported by Ren et al., who observed a greater degree of mucosal thickening in association with vertical defects (90.2%).[20]

The dense cortical bone, which exhibits variability in thickness, usually separates the maxillary sinus membrane and maxillary posterior teeth. On occasion, this separation is confined to the mucoperiosteum. The infection from the teeth has various routes to enter the sinus cavity, including direct spread via the porous maxillary bone, as well as spread through the vascular and lymphatic channels. Therefore, it can be suggested that the proximity of a diseased tooth to the sinus lining is associated with an increased probability of infectivity transmission.[1,22]

One of the crucial criteria in the assessment of Schneiderian membrane thickening is the gap between the apical extent of the alveolar bone that supports the affected tooth and the crest of the sinus or lining, referred to as RHAB. According to Bornstein et al., the inflammatory reaction may cause thickening of the bone apical to periapical lesion as well as thickening of the mucous membrane of the maxillary sinus.[22] However, very little research has been conducted to establish a relationship between RHAB and MT.[1,23] The maximum thickness of the maxillary sinus mucosa was shown to be inversely linked with RHAB in the current investigation ($r = -0.660$, $p = 0.046$). The majority of sinus linings (89.5%) exhibited a substantial increase in MT when RHAB was less than 4 mm.

In the present study, MT was shown to be substantially associated with maxillary first and second molars, as well as second premolars, with a prevalence of 82.6%, 83.3% and 75.8%, respectively. This is in line with the study by Zhang et al. who examined the association between MT and maxillary first and second molars.[1]

In healthy individuals, MT of the sinus membrane averages 1 mm. However, thicker sinus membranes of up to 2 mm have been observed to be less susceptible to membrane perforation during sinus elevation procedures. Mucosal thickening of more than 2 mm, on the other hand, has been positively linked with sinus membrane perforation.[24,25] The current study demonstrated a correlation between MT and periodontitis, with respect to residual alveolar bone height and the extent of bone loss. Furthermore, mucosal thickening measurements exhibited statistically significant correlations with the extent of bone loss and RHAB.

Limitations

Certain limitations must be considered when interpreting the results of the study. The assessment of changes in membrane thickness after periodontal treatment could reveal more about the association of the disease with sinus membrane thickening. A histological or microbiological examination of the thickened sinus membrane could have elucidated the association between periodontitis and Schneiderian membrane thickening.

Conclusions

Mucosal thickening is associated with periodontitis and is proportional to the extent of bone loss. Horizontal defects show the highest incidence of mucosal thickening.

The extent of alveolar bone loss and RHAB adjacent to the infected molar are the 2 major factors related to alterations in MT. Patients with substantial furcation involvement should be questioned about sinus problems, especially if the sinus is adjacent to the teeth. While the prevalence of this type of condition is relatively low, proper evaluation and diagnosis could help avoid consequences. In patients considering implant placement, CBCT might be a useful tool for detecting periodontitis-related alterations in the sinus membrane.

Ethics approval and consent to participate

The Institutional Ethics Committee of Vishnu Dental College, Bhimavaram, India, approved the study protocol, which adhered to the 2013 Declaration of Helsinki.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Use of AI and AI-assisted technologies

Not applicable.

ORCID iDs

Sathyavalli Veluri https://orcid.org/0000-0003-2707-9348
Sruthima Naga Venkata Satya Gottumukkala https://orcid.org/0000-0002-7126-5829
Gautami Penmetsa https://orcid.org/0000-0002-8744-1452
Ramesh Santosh Venkata Konathala https://orcid.org/0000-0001-7022-0023
Geetanjali Darna https://orcid.org/0000-0002-2249-7113
Mohan Kumar Pasupuleti https://orcid.org/0000-0001-7797-1890
Satyanarayana Raju Mantena https://orcid.org/0000-0002-7952-8312

References

1. Zhang B, Wei Y, Cao J, et al. Association between the dimensions of the maxillary sinus membrane and molar periodontal status: A retrospective CBCT study. *J Periodontol*. 2020;91(11):1429–1435. doi:10.1002/JPER.19-0391
2. Lathiya VN, Kolte AP, Kolte RA, Mody DR. Effect of periodontal therapy on maxillary sinus mucous membrane thickening in chronic periodontitis: A split-mouth study. *J Dent Res Dent Clin Dent Prospects*. 2018;12(3):166–173. doi:10.15171/joddd.2018.026
3. Zaki SM, Ahmed MAA, Hameed HM. Periodontal health status of patients with maxillary chronic rhinosinusitis (Part 3: Associated factors and correlations). *Int J Adv Res Biol Sci*. 2016;3(8):218–225. https://ijarbs.com/pdfcopy/aug2016/ijarbs35.pdf. Accessed December 21, 2021.
4. Dave M, Loughlin A, Walker E, Davies J. Challenges in plain film radiographic diagnosis for the dental team: A review of the maxillary sinus. *Br Dent J*. 2020;228(8):587–594. doi:10.1038/s41415-020-1524-8
5. Constantine S, Clark B, Kiermeier A, Anderson PP. Panoramic radiography is of limited value in the evaluation of maxillary sinus disease. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;127(3):237–246. doi:10.1016/j.oooo.2018.10.005
6. Tadinada A, Fung K, Thacker S, Mahdian M, Jadhav A, Schincaglia GP. Radiographic evaluation of the maxillary sinus prior to dental implant therapy: A comparison between two-dimensional and three-dimensional radiographic imaging. *Imaging Sci Dent*. 2015;45(3):169–174. doi:10.5624/isd.2015.45.3.169
7. Perrotti G, Baccaglione G, Clauser T, et al. Total face approach (TFA) 3D cephalometry and superimposition in orthognathic surgery: Evaluation of the vertical dimensions in a consecutive series. *Methods Protoc*. 2021;4(2):36. doi:10.3390/mps4020036
8. Alhammadi MS, Al-Mashraqi AA, Alnami RH, et al. Accuracy and reproducibility of facial measurements of digital photographs and wrapped cone beam computed tomography (CBCT) photographs. *Diagnostics (Basel)*. 2021;11(5):757. doi:10.3390/diagnostics11050757
9. Maestre-Ferrín L, Galán-Gil S, Carrillo-García C, Peñarrocha-Diago M. Radiographic findings in the maxillary sinus: Comparison of panoramic radiography with computed tomography. *Int J Oral Maxillofac Implants*. 2011;26(2):341–346. PMID:21483887.
10. Shanbhag S, Karnik P, Shirke P, Shanbhag V. Cone-beam computed tomographic analysis of sinus membrane thickness, ostium patency, and residual ridge heights in the posterior maxilla: Implications for sinus floor elevation. *Clin Oral Implants Res*. 2014;25(6):755–760. doi:10.1111/clr.12168
11. Yoo JY, Pi SH, Kim YS, Jeong SN, You HK. Healing pattern of the mucous membrane after tooth extraction in the maxillary sinus. *J Periodontal Implant Sci*. 2011;41(1):23–29. doi:10.5051/jpis.2011.41.1.23
12. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. *J Periodontol*. 2018;89 Suppl 1:S159–S172. doi:10.1002/JPER.18-0006
13. Munakata M, Yamaguchi K, Sato D, Yajima N, Tachikawa N. Factors influencing the sinus membrane thickness in edentulous regions: A cone-beam computed tomography study. *Int J Implant Dent*. 2021;7(1):16. doi:10.1186/s40729-021-00298-y
14. Eggmann F, Connert T, Bühler J, Dagassan-Berndt D, Weiger R, Walter C. Do periapical and periodontal pathologies affect Schneiderian membrane appearance? Systematic review of studies using cone-beam computed tomography. *Clin Oral Investig*. 2017;21(5):1611–1630. doi:10.1007/s00784-016-1944-7
15. Sakir M, Yalcinkaya SE. Associations between periapical health of maxillary molars and mucosal thickening of maxillary sinuses in cone-beam computed tomographic images: A retrospective study. *J Endod*. 2020;46(3):397–403. doi:10.1016/j.joen.2019.12.004
16. Shanbhag S, Karnik P, Shirke P, Shanbhag V. Association between periapical lesions and maxillary sinus mucosal thickening: A retrospective cone-beam computed tomographic study. *J Endod*. 2013;39(7):853–857. doi:10.1016/j.joen.2013.04.010
17. Dagassan-Berndt DC, Zitzmann NU, Lambrecht JT, Weiger R, Walter C. Is the Schneiderian membrane thickness affected by periodontal disease? A cone beam computed tomography-based extended case series. *J Int Acad Periodontol*. 2013;15(3):75–82. PMID:24079099.
18. Phothikhun S, Suphanantachat S, Chuenchompoonut V, Nisapakultorn K. Cone-beam computed tomographic evidence of the association between periodontal bone loss and mucosal thickening of the maxillary sinus. *J Periodontol*. 2012;83(5):557–564. doi:10.1902/jop.2011.110376
19. Vallo J, Suominen-Taipale L, Huumonen S, Soikkonen K, Norblad A. Prevalence of mucosal abnormalities of the maxillary sinus and their relationship to dental disease in panoramic radiography: Results from the Health 2000 Health Examination Survey. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010;109(3):e80–e87. doi:10.1016/j.tripleo.2009.10.031
20. Ren S, Zhao H, Liu J, Wang Q, Pan Y. Significance of maxillary sinus mucosal thickening in patients with periodontal disease. *Int Dent J*. 2015;65(6):303–310. doi:10.1111/idj.12186
21. Janner SFM, Caversaccio MD, Dubach P, Sendi P, Buser D, Bornstein MM. Characteristics and dimensions of the Schneiderian membrane: A radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in the posterior maxilla. *Clin Oral Implants Res*. 2011;22(12):1446–1453. doi:10.1111/j.1600-0501.2010.02140.x
22. Bornstein MM, Wasmer J, Sendi P, Janner SFM, Buser D, von Arx T. Characteristics and dimensions of the Schneiderian membrane and apical bone in maxillary molars referred for apical surgery: A comparative radiographic analysis using limited cone beam computed tomography. *J Endod*. 2012;38(1):51–57. doi:10.1016/j.joen.2011.09.023

23. Apparaju V, Velamati SC, Karnati L, Salahshoor A, Nateghi F, Vaddamanu SK. Does residual bone thickness apical to periodontal defect play a major role in maxillary sinus mucous membrane thickness?: A cone-beam computed tomography-assisted retrospective study. *Dent Res J (Isfahan)*. 2019;16(4):251–256. PMID:31303880.
24. Monje A, Diaz KT, Aranda L, Insua A, Garcia-Nogales A, Wang HL. Schneiderian membrane thickness and clinical implications for sinus augmentation: A systematic review and meta-regression analyses. *J Periodontol*. 2016;87(8):888–899. doi:10.1902/jop.2016.160041
25. Pommer B, Dvorak G, Jesch P, Palmer RM, Watzek G, Gahleitner A. Effect of maxillary sinus floor augmentation on sinus membrane thickness in computed tomography. *J Periodontol*. 2012;83(5):551–556. doi:10.1902/jop.2011.110345