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Evaluating the relationship between periodontal bone loss in maxillary posterior teeth and Schneiderian membrane thickness

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Abstract

Background To understand the potential impact of periodontal disease on maxillary sinus health, this study aimed to evaluate the relationship between periodontal bone loss and maxillary sinus membrane thickness using cone beam computed tomography (CBCT).

Methods Nine hundred thirty-nine maxillary posterior segment images from 527 subjects were retrospectively scanned via CBCT. A total of 826 premolar, 701 first molar and 817 s molar teeth were examined. The maxillary sinuses in each segment were divided into anterior, median and posterior regions according to the tooth roots they were associated with, and their membrane thicknesses were measured and categorized. The effects of age and gender on membrane thickness were evaluated. T tests and one-way ANOVA were used to analyze differences between groups, followed by post hoc Tukey tests for multiple comparisons. Additionally, correlation analyses were performed to investigate the relationships between the categorized membrane thicknesses and periodontal bone loss.

Results A significant positive correlation was found between maxillary sinus membrane thickness and periodontal bone loss in all three regions ($p < 0.05$). Periodontal bone loss was greater in regions with class IV membrane thickness ($p < 0.001$). Sinus membrane thickness and periodontal bone loss were greater in men and older people ($p < 0.001$).

Conclusions This study found a relationship between maxillary sinus membrane thickness and bone loss due to periodontal disease in the maxillary posterior region. Considering the relationship between periodontal disease and sinus infections, it can be concluded that progressive and untreated periodontal disease may be associated with infections in close anatomical structures such as the maxillary sinus. These results may contribute to the development of clinical decisions and treatment plans in implantology practices.

Keywords CBCT, Maxillary sinus, Periodontal bone loss, Sinus membrane thickness, Schneiderian membrane

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Background

The maxillary sinuses, which are the largest air-filled cavities among the paranasal sinuses, typically contain approximately 15 milliliters of air in adults [1]. Situated near the nasal cavity, these sinuses are notable for their location: the superior border of the sinus forms the floor of the orbit, and the apex of the sinus is a pyramid-shaped structure pointing toward the zygomatic process [1]. Stretching from the area of the canine and premolar teeth toward the tuber of the posterior maxilla, this region often aligns closely with the roots of the posterior teeth, making it a critical area in dental anatomy and sinus health [2].

The maxillary sinuses are frequently affected by pathologies in this region due to their close proximity to the maxillary posterior teeth. In healthy situations, the maxillary sinuses are covered with a thin respiratory mucosa called the Schneiderian membrane, which is approximately 1 mm thick and adheres to the periosteum [3–5]. Due to the thin structure of the membrane, it is difficult to distinguish it on radiographic images in healthy situations; the thickening of the membrane under pathological conditions facilitates its visualization on radiographic images [6, 7]. Cone beam computed tomography (CBCT) is an imaging method recommended for the evaluation of the anatomical and morphological structure of the maxillary sinus because it reveals anatomical structures without distortion and provides information about bone size and morphology [8–10].

Currently, due to longer life expectancies and longer exposure to chronic dental diseases, the incidence of sinus pathologies associated with periodontal diseases may increase. Therefore, understanding the dynamic interplay between periodontal health and sinus conditions is critical not only for effective treatment but also for preventive care. Additionally, as implantology evolves, the demand for precise assessments of bone and sinus conditions has grown, underscoring the need for detailed studies such as the current one.

Maxillary sinusitis of odontogenic origin is considered the main cause of membrane thickening [4]. Dental abscesses and periodontal diseases stand out as the most prevalent causes of odontogenic sinusitis, impacting the Schneiderian membrane [4, 11, 12]. Thickening of the maxillary sinus mucosa may occur as a consequence of loss of the alveolar bone surrounding the molar teeth due to periodontal disease [13, 14]. Sinus augmentation surgery procedures are often preferred for implant placement in cases where the alveolar crest height in the maxillary posterior region is insufficient. In these procedures, factors such as sinus membrane thickness (MT) and periodontal health status are important factors affecting the success of sinus augmentation and implant placement. The aim of this study was to evaluate the relationship between periodontal bone loss (PBL) and Schneiderian MT using CBCT images and to provide guidance on the factors affecting success in sinus augmentation surgery.

Methods

This study was conducted with the approval of the Eskişehir Osmangazi University Non-Interventional Clinical Research Ethics Committee, dated 14.07.2020 and numbered 29. Patients who provided written informed consent were included in the study, and the archived anamnesis files and radiology records of the subjects included in the study were examined.

CBCT (Promax 3D Mid; Planmeca, Helsinki, Finland) images of subjects who visited the Eskişehir Osmangazi University Faculty of Dentistry with various complaints were evaluated. All images were retrospectively retrieved from the archive of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Eskişehir Osmangazi University, between 2016 and 2020.

The parameters used in this research were maxillary sinus MT, number of maxillary posterior teeth, amount of PBL in these areas, and subject age and gender [7].

CBCT images of 939 maxillary posterior segments from 527 systemically healthy individuals aged 18 years and older were included in this study. In all images, the occlusal plane was taken parallel to the ground, and there was at least one maxillary posterior tooth under the examined sinus areas.

Images from subjects with a history of smoking, acute sinusitis, pathological formations in the maxillary sinus (such as mucoceles, retention cysts, or polyps), toothless maxillary posterior regions, or subjects with caries, fillings, canal fillings, periapical lesions, or prosthetic restorations on the maxillary posterior teeth, were excluded from the study. Additionally, CBCT images with poor image quality and motion artifacts and rare cases such as trauma were not included.

Image analysis

All of the images were tomographic images taken with the same CBCT device with the following parameters: 94 kVp, 14 mA, 27 s scanning time and with the subject standing. CBCT measurements were made in Planmeca Romexis (Planmeca Romexis software, version 6.2.4, Helsinki, Finland) software. Images were evaluated using cross-sectional sections obtained at 2 mm intervals.

All CBCT images were evaluated by a researcher with at least 5 years of dental experience (C.E.). One hundred specimens were measured twice with a one week by the examiner who made the evaluation before the radiomorphometric evaluation. The arithmetic mean of these two measurements was recorded and included in this study. Intraclass correlation coefficients were used to evaluate the intra-examiner agreement and reliability.

The intraclass correlation coefficients (95% confidence interval) were 0.971 (0.949–0.982) for MT, 0.978 (0.967–0.985) for PBL.

Evaluation of sinus MT

In the sagittal images, the anterior section of the floor of the maxillary sinus was determined as the region between the root tips of the maxillary premolars; the median section was determined as the region at the level of the apex of the first molar; and the posterior section was determined as the region between the root tips of the second and third molars (Fig. 1) [7].

In cross-sectional sections, the thickness of the sinus membrane was measured perpendicular in millimeters from the floor of the sinus to the highest border of the mucosa (Fig. 2) [3, 4, 15, 16]; thus, three different measurements were made for each sinus: anterior, median, and posterior. The measurements were repeated and recorded for each segment. In cases where the sinus floor boundaries were not clearly visible in certain CBCT sections (MT measurement between 0.9 and 1 mm), a standardized distance of 1 mm was assumed for the measurements [14]. Images where MT measurements were not possible were not included in the analysis.

The sinus MT was divided into five groups:

Class I: 0–1 (≤1) mm;
Class II: 1–2 (≤2) mm;
Class III: 2–4 (≤4) mm;
Class IV: 4–10 (≤10) mm;
Class V: >10 mm [3, 16].

Evaluation of PBL

To measure PBL, sections were selected where the alveolar bone margins of premolars and molars were vividly visible in CBCT. Within the cross-sectional sections, the distance between the alveolar bone margin and the cemento-enamel junction (CEJ) of each posterior tooth was measured perpendicularly (Fig. 3).

Measurements were taken from two surfaces of each tooth to determine the alveolar bone loss on the

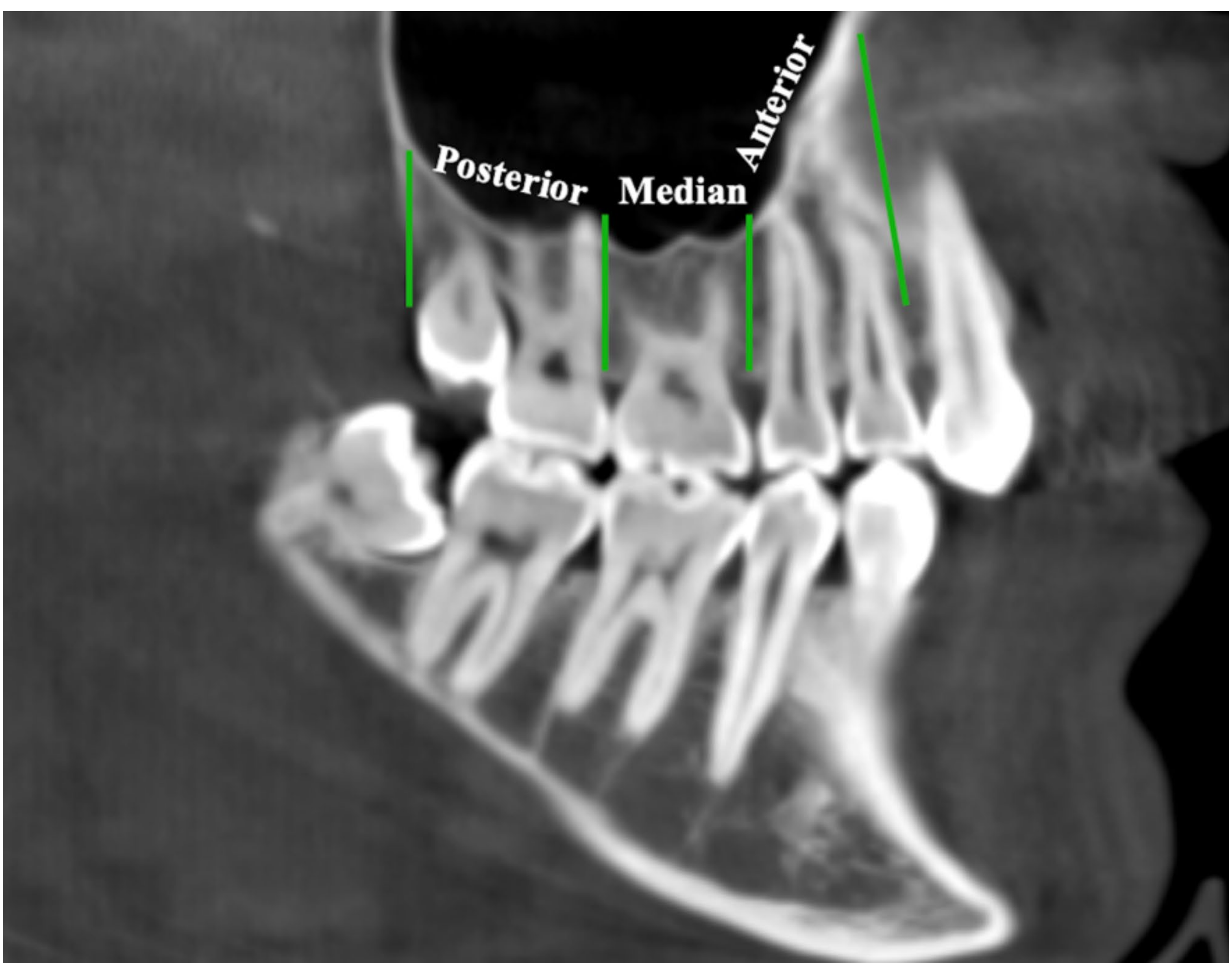

Fig. 1 Anterior, median and posterior sections of the maxillary sinus membrane in sagittal images

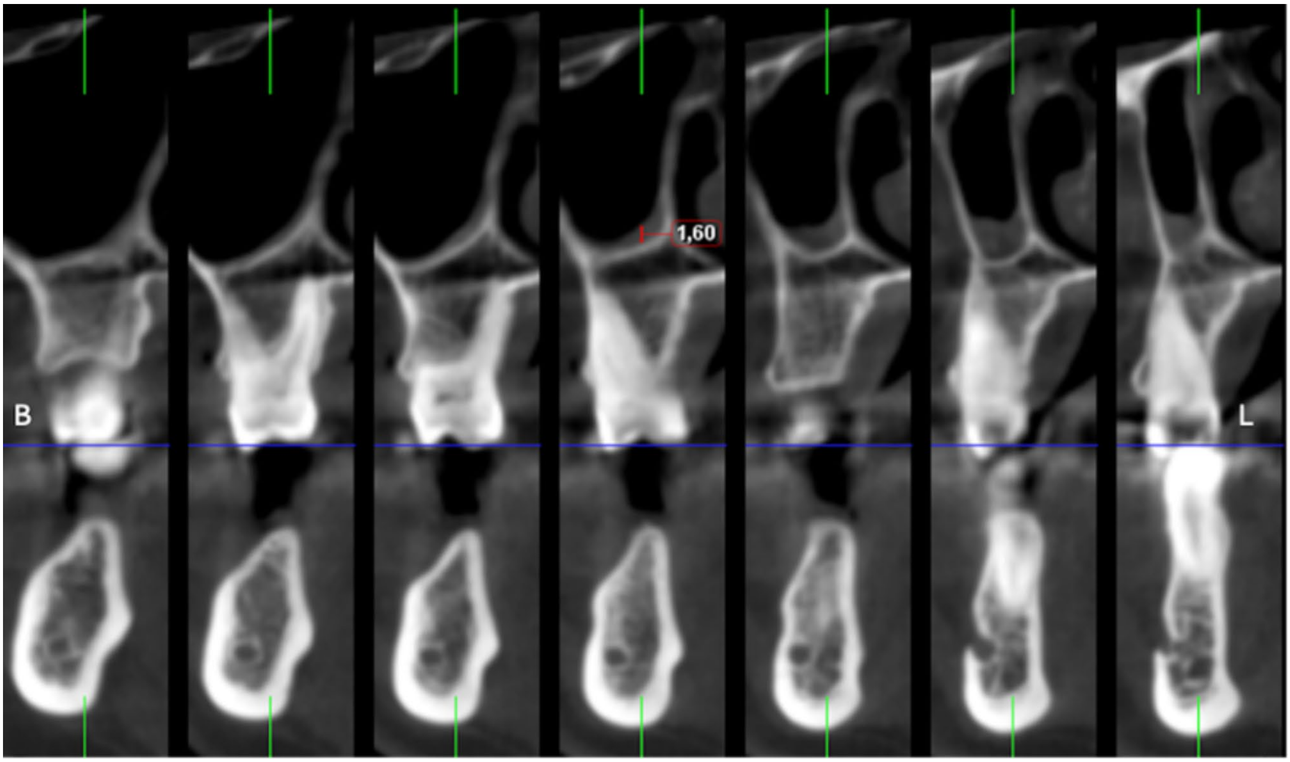

Fig. 2 Measurement of the thickness of the maxillary sinus membrane in cross-sectional images

buccal and palatal surfaces (Fig. 4). The standard distance between the normal alveolar bone margin and the CEJ was regarded as 1 mm, and this value was subtracted from the measured values [14, 17, 18]. The highest value in each region was considered for analysis.

In the cross-sectional section, the measurement of periodontal bone loss and sinus membrane thickness in posterior teeth is illustrated in Fig. 5.

Evaluation of age, gender and segment

Individuals in different age ranges were grouped as follows:

Group I: 18–25 years;
Group II: 26–40 years;
Group III: 41–60 years;
Group IV: >60 years [3].

The relationships of sinus MT and PBL with age group, gender, and the right and left segments of the maxilla were evaluated.

Statistical analysis

Statistical analyses were performed using SPSS software, version 20.0 (IBM Corp., New York, USA). Prior to conducting the main analyses, a power analysis was carried out to ensure that the study was adequately powered to detect the hypothesized effects. The analysis revealed that with an effect size of 0.25 and a 5% margin of error, our study achieved a power level of 99%. To assess the relationships between maxillary sinus MT and PBL and their interactions with age and gender, both t tests and one-way analysis of variance (ANOVA) were utilized. Differences across groups were further examined using Tukey's post hoc tests to control for multiple comparisons. Additionally, correlation analyses were conducted to explore the direction and strength of the associations between PBL and sinus MT. The significance level was set at $p < 0.05$ for all statistical tests.

Results

CBCT images of 939 maxillary posterior segments and 2344 posterior teeth from 527 subjects aged between 18 and 86 years (mean age: 36.29 ± 14.23) were examined.

Prevalence of MT

When examining the distribution of anterior MT according to the 826 premolar teeth, the percentage of Class I MT was 31.1% ($n = 257$), the percentage of Class II MT was 27.2% ($n = 225$), the percentage of Class III MT was 34.3% ($n = 283$), and the percentage of Class IV MT was 7.4% ($n = 61$) (Table 1).

When the median MT distribution according to 701 first molar teeth was examined, the percentage of Class I MTs was 33.7% ($n = 236$), the percentage of Class II MTs was 29.5% ($n = 207$), the percentage of Class III MTs was 29.2% ($n = 205$), the percentage of Class IV MTs was 7.3%

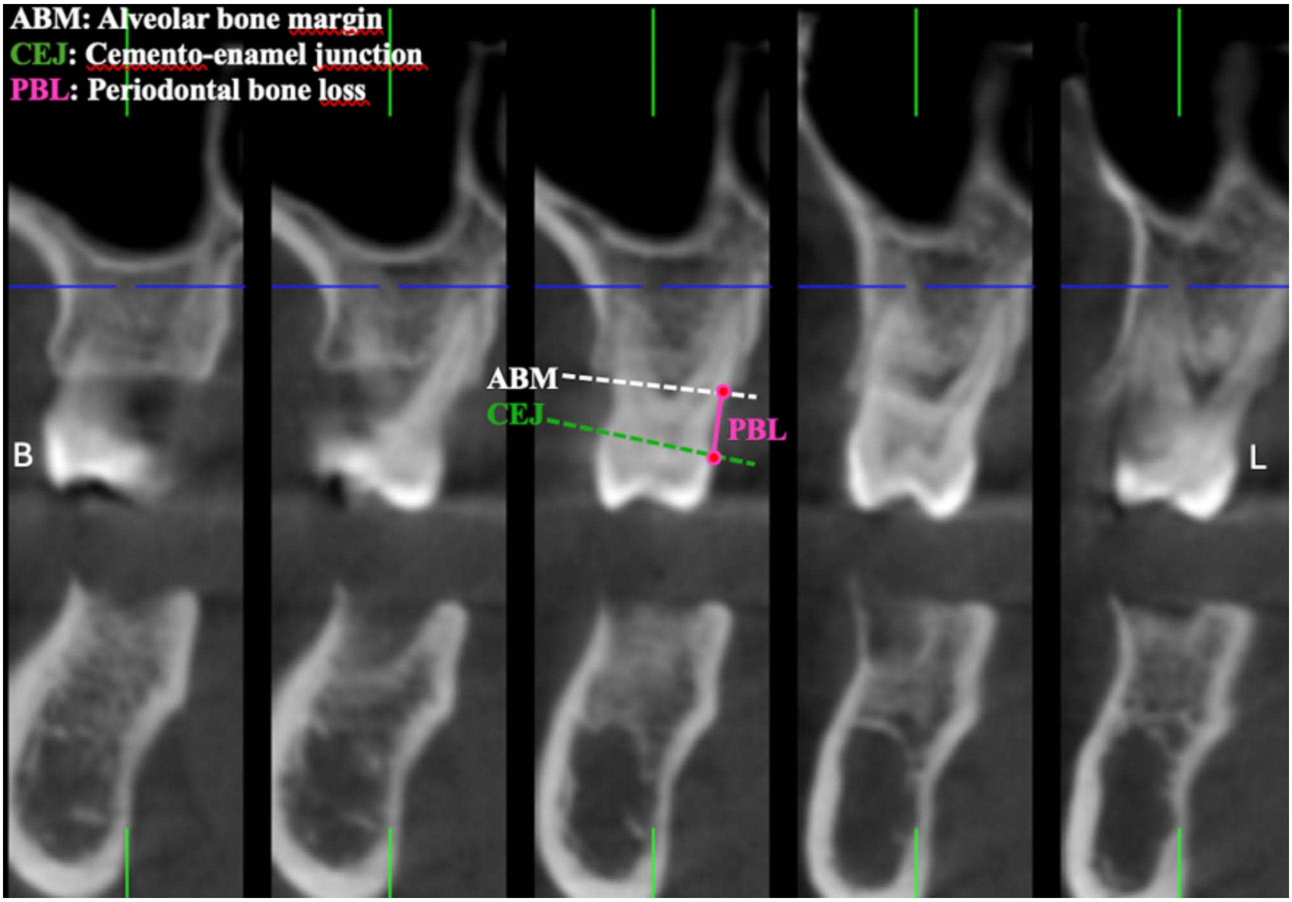

Fig. 3 Determination of the alveolar bone margin (ABM), cemento-enamel junction (CEJ), and periodontal bone loss (PBL) in cross-sectional images

($n = 51$) and the percentage of Class V MTs was 0.3% ($n = 2$) (Table 1).

When the posterior MT distribution according to the 817 s molar teeth was examined, the percentage of Class I MT was 37.1% ($n = 303$), the percentage of Class II MT was 28.6% ($n = 234$), the percentage of Class III MT was 27.4% ($n = 224$) and the percentage of Class IV MT was 6.9% ($n = 56$) (Table 1).

Relationship between MT and the PBL

Premolar teeth: Significant differences in PBL were noted across anterior MT classes ($p < 0.001$). The class IV MT exhibited the highest PBL, which was significantly greater than that of all of the other classes. PBL sequentially decreased from Class IV to I (Table 1).

First molar teeth: PBL varied significantly with the median MT classification ($p < 0.001$), with Class V MT showing the highest PBL, which was significantly greater than that of the other classes. PBL decreased sequentially from Class IV to Class I (Table 1).

Second molar teeth: Significant variation in the PBL with respect to the posterior MT class was observed ($p < 0.001$). The class IV MT had the highest PBL, with significant decreases noted in the lower classes (Table 1).

Strong positive correlations were found between the anterior, median, and posterior MT and PBL, with correlation coefficients (r) of 0.863 for premolars, 0.911 for first molars, and 0.899 for second molars ($p < 0.05$).

Relationship between MT and age

The distribution was as follows: 37.1% in the 18–25 age group, 25.9% in the 26–40 age group, 32.5% in the 41–60 age group, and 4.6% in the over 60 age group. Among all age groups, Group IV had the largest MTs in the anterior, median and posterior regions ($p < 0.001$) (Table 2).

Relationship between MT and gender

Of the subjects included in the study, 54.08% ($n = 285$) were female, and 45.92% ($n = 242$) were male. The anterior, median, and posterior MT differed significantly according to gender ($p < 0.001$), and the MT in men was significantly greater than that in women in all three regions, as detailed in Table 2.

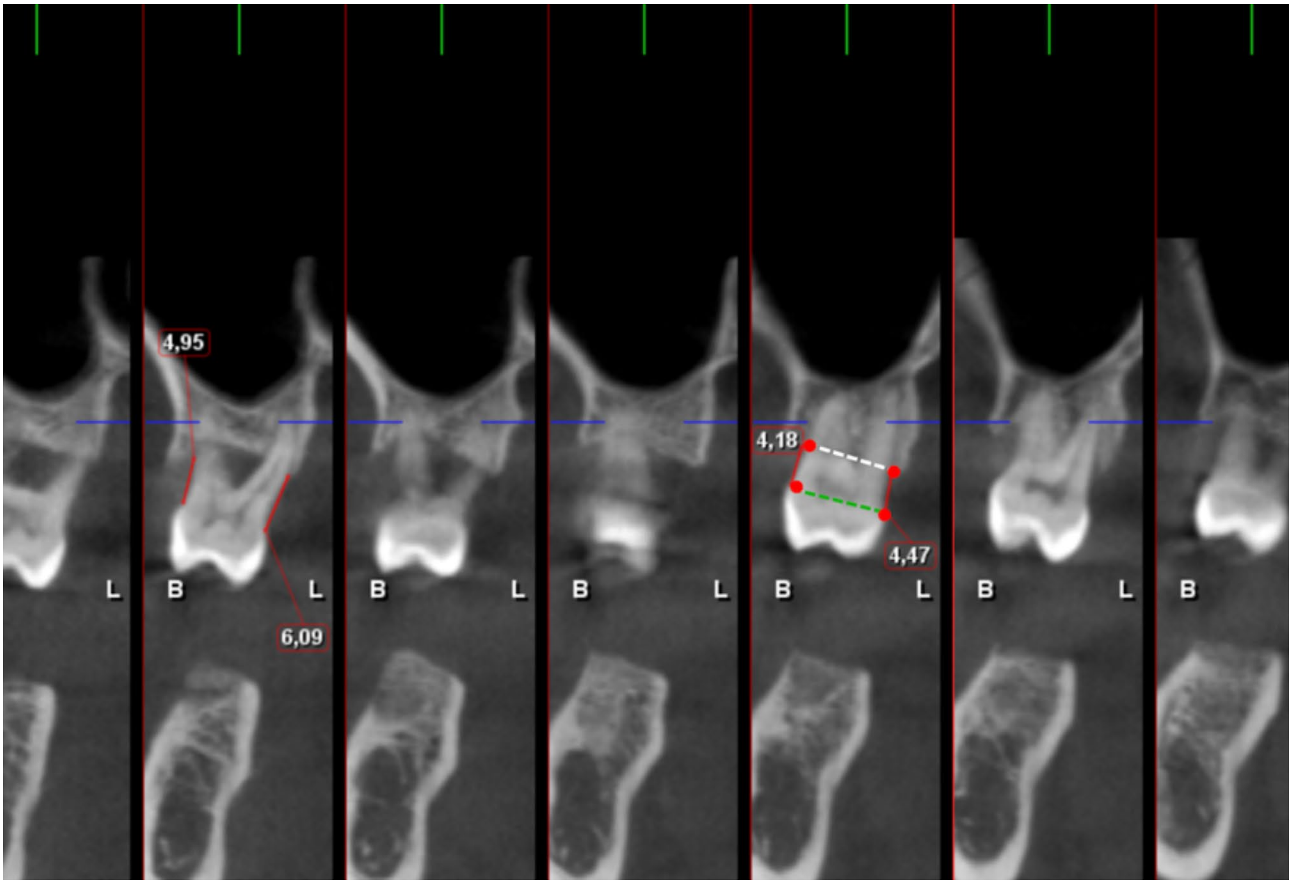

Fig. 4 Measurement of the periodontal bone loss in cross-sectional images: alveolar bone margin (white dotted line), cemento-enamel junction (green dotted line), periodontal bone loss (red line)

Relationship between MT and segment

The distribution of the segments examined was 51.3% in the maxillary right segment and 48.7% in the maxillary left segment. The anterior, median and posterior MT did not differ significantly according to segment ($p > 0.05$). The mean MT levels between the right and left segments were similar (Table 2).

Relationship between PBL and age

Among all age groups, Group IV had the largest PBLs in the premolar, first molar and second molar teeth regions ($p < 0.001$) (Table 3).

Relationship between PBL and gender

PBL levels in the premolar, first molar and second molar tooth areas differed significantly according to gender ($p < 0.001$). The amount of PBL in men was significantly greater than that in women in every region, as illustrated in Table 3.

Relationship between PBL and segment

PBL levels in the premolar tooth area differed significantly according to segment ($p < 0.05$). The mean PBL in the maxillary right segment was significantly greater than that in the maxillary left segment (Table 3).

MT and PBL, age, gender relationships

Group I, female Individuals with Class III anterior sinus MT in the premolar teeth area exhibited greater PBL ($p < 0.001$). Individuals with Class III median sinus MT in the first molar teeth are exhibited greater PBL ($p < 0.05$).

Group I, male Individuals with Class III anterior sinus MT in the premolar teeth and Class III median sinus MT in the first molar teeth area exhibited greater PBL ($p < 0.05$).

Group II, male Individuals with Class III anterior sinus MT in the premolar teeth area exhibited greater PBL ($p < 0.05$).
These findings are detailed in Table 4, which illustrates the distribution and severity of PBL relative to MT classifications across different age and gender groups.

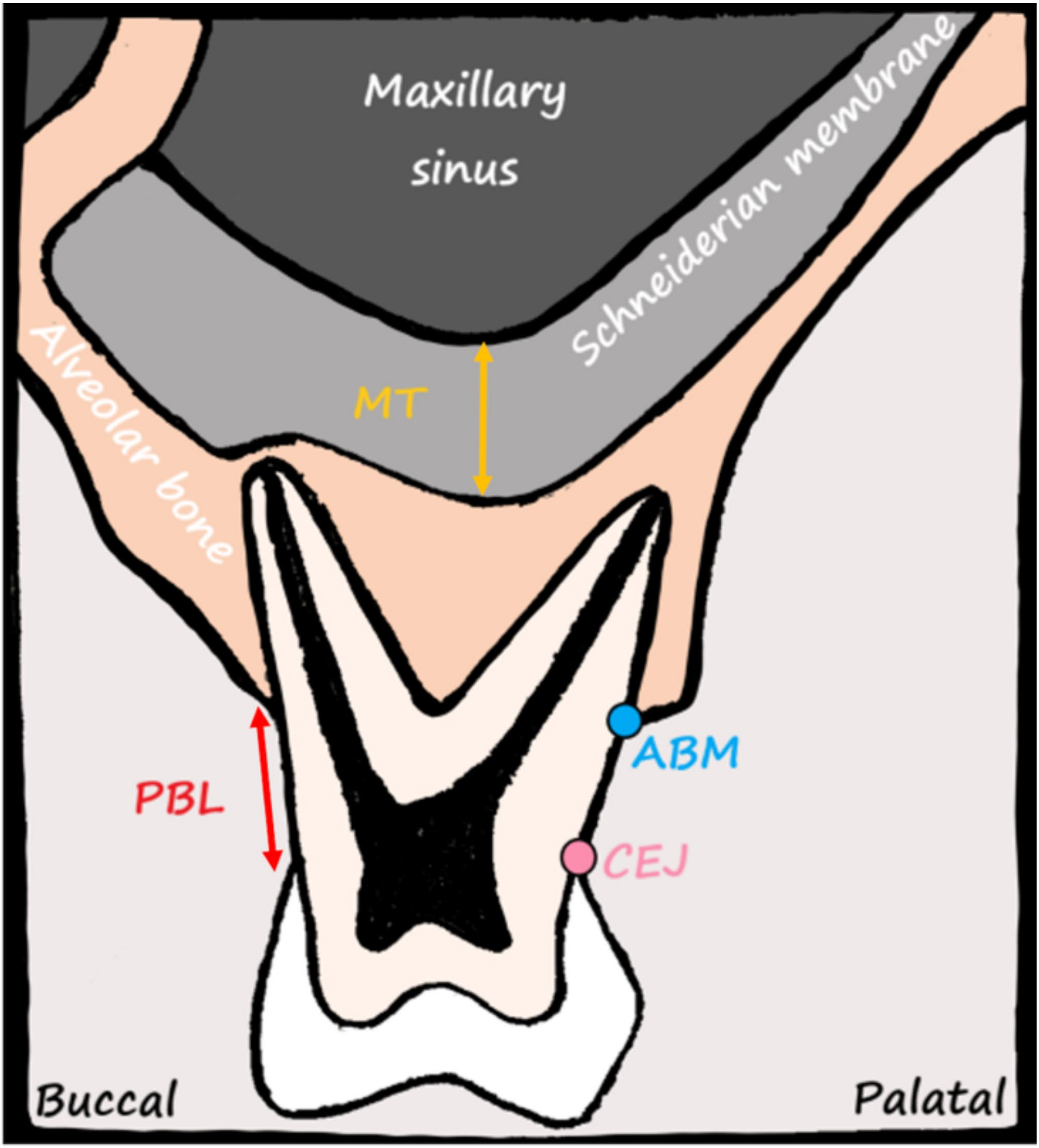

Fig. 5 Illustration of periodontal bone loss and sinus membrane thickness measurement in cross-sectional images of posterior teeth. PBL (Periodontal bone loss), ABM (Alveolar bone margin), CEJ (Cemento-enamel junction), MT (Membrane thickness)

Discussion

In this study, the relationship between Schneiderian MT and PBL was analyzed radiographically, and increased membrane thickening was found in subjects with radiographic signs of PBL.

The methods section of this study was standardized to ensure originality in the results. Factors like smoking [19, 20], and odontogenic conditions [21] (such as caries, periapical lesions, fillings, root canal treatments, and prosthetic restorations excluding periodontal diseases), along with sinus pathologies, were excluded due to their potential influence on the study outcomes. This study offers a more comprehensive radiographic dataset compared to similar studies.

The findings of the present study support the involvement of periodontal disease in the augmentation of Schneiderian MT, which contributes to odontogenic sinusitis. These results align with the conclusions drawn by Phothikhun et al. [4] and Sheikhi et al. [15], indicating a consistent trend wherein membrane thickening correlates with PBL. Literature reviews further substantiate these findings, demonstrating an increase in the levels of pathogenic bacteria and inflammatory mediators in teeth afflicted with severe periodontitis [22]. It is obvious that these factors can reach the porous maxilla through blood and lymph vessels or directly infiltrate the sinus mucosa, causing membrane thickening [11–13, 22]. Furthermore, prior research has indicated that successful periodontal treatment may lead to a partial reduction in maxillary sinus MT [23, 24]. These findings are consistent with the outcomes of the current study and lend additional support to the hypothesis implicating periodontal disease in membrane thickening observed in asymptomatic individuals, as well as the link between periodontal infection and odontogenic sinusitis.

CBCT images were used to evaluate the maxillary sinus MT in the present study, and conventional radiographic techniques were used in several previous studies [21, 25]. Compared to similar imaging methods, CBCT offers high image quality, accuracy in the location of anatomical structures, short scanning time, and reduced absorbed radiation dose. It is widely used in dental practice because of these advantages [26]. A study by Cymerman et al. [27] concluded that CBCT detected sinus membrane thickening four times more frequently than did conventional periapical radiographs, proving its usefulness in distinguishing the etiological cause of maxillary sinus pathology. Furthermore, distinguishing between infection-related membrane thickening, cysts, and tumors can be challenging using two-dimensional radiographic techniques [28]. Studies comparing the effectiveness of three-dimensional volumetric images versus two-dimensional images in detecting and classifying bone defects have consistently demonstrated that CBCT exhibits greater sensitivity [29, 30].

Phothikhun et al. [4] utilized CBCT to assess the correlation between PBL and sinus mucosa thickness, revealing a link between severe PBL and membrane thickening. Similarly, Vallo et al. [21] reported an association between membrane thickening and various periodontal pathologies, including horizontal-vertical bone loss and furcation lesions. Moreover, Yoo et al. [11] noted more pronounced thickening of the sinus membrane in regions where teeth were extracted due to periodontal disease than in regions where teeth were extracted for

Table 1 Relationship between maxillary sinus membrane thickness and periodontal bone loss

	Premolar					I. Molar					II. Molar			
Anterior MT	***n***	**PBL (mm)**	**Std.**	***p***	**Median MT**	***n***	**PBL (mm)**	**Std.**	***p***	**Posterior MT**	***n***	**PBL (mm)**	**Std.**	***p***
Class I	257	1.29	0.44	0.000*	Class I	236	1.22	0.54	0.000*	Class I	303	1.10	0.51	0.000*
Class II	225	1.86	0.65		Class II	207	1.83	0.62		Class II	234	1.78	0.66	
Class III	283	3.02	0.86		Class III	205	3.02	0.86		Class III	224	2.98	0.83	
Class IV	61	5.26	1.12		Class IV	51	5.78	1.57		Class IV	56	5.61	1.26	
Class V	-	-	-		Class V	2	12.36	1.51		Class V	-	-	-	
Total	826	2.33	1.31		Total	701	2.3	1.55		Total	817	2.12	1.4	

*$p < 0.001$

n: Number of teeth, MT: Membrane thickness, PBL: Periodontal bone loss, Std: Standard deviation endodontic problems or root fractures. These findings support the relationship between periodontal disease and membrane thickening, consistent with the results of our study. Conversely, in their study, Janner et al. [7] did not find an association between periodontal lesions and membrane thickening. This disparity in results has been attributed to differences in the demographics of the study populations [7].

The criteria used to define MT vary between studies [21, 25]. No cutoff was applied for pathological membrane thickening in this study. The average maxillary sinus MT was 2.05 ± 1.25 mm. Similarly, in the radiographic study by Soikkonen and Ainamo [25], where they evaluated maxillary sinus findings in geriatric patients, no criterion for membrane thickening was defined. According to the literature, the average thickness of a normal Schneiderian membrane is 1 mm [3–5]. Most studies related to pathological MT have reported an MT of >2 mm as mucosal thickening [3, 7, 21, 31, 32]. This value correlates to Class III, IV, and V MT in this current study. From the findings of our study, we determined a higher rate of alveolar bone resorption as MT increased. This finding reinforces the theory that periodontal disease causes MT when other factors are excluded. Increased inflammatory cytokines and pathogenic bacteria in teeth with periodontitis could directly reach the sinus mucosa directly by passing through periodontal pockets or gingival tissue, thus causing the sinus mucosa to thicken [4, 22].

In our research, thickening >10 mm was rarely observed ($n=2$). In the study by Phothikhun et al. [4] evaluating the relationship between MT and PBL, the average MT was found to be 5 mm; similarly, thickening greater than 10 mm was not common. The criteria we established for identifying to define sinus membrane thickening in our study are images exhibiting homogeneous density, regular and clear boundaries, a parallel orientation to the sinus floor, and the absence of cystic or nodular formation within the sinus cavity [31]. These criteria allow for the differentiation of MT from other pathological formations, suggesting that the images evaluated in our study might represent MT exclusively. Consequently, only two images displaying MT greater than 10 mm were included in the analysis. Nevertheless, future studies may benefit from involving the otolaryngology service or employing additional imaging methods in cases where pathology is suspected, thereby improving the accuracy of the findings.

In this study, a relationship between age and increased membrane thickening was observed. A significant increase in both PBL and sinus MT was detected with increasing age in our study ($p<0.001$). Accordingly, both MT and PBL were greater in men and in older individuals (>60 years). These findings are in line with prior research

Table 2 Relationships between membrane thickness, age, gender, segment

Parameter		Anterior MT				Median MT				Posterior MT			
		n	MT (mm)	Std.	*p*	*n*	MT (mm)	Std.	*p*	*n*	MT (mm)	Std.	*p*
Age	Group I	341	1.38	0.56	0.000*	327	1.40	0.61	0.000*	348	1.31	0.57	0.000*
	Group II	208	2.11	0.90		165	2.08	0.89		212	1.99	0.80	
	Group III	240	2.78	1.32		191	3.07	1.80		230	2.80	1.43	
	Group IV	37	3.77	1.40		18	3.86	1.49		27	4.19	1.69	
Gender	Female	456	1.86	1.02	0.000*	411	1.93	1.24	0.000*	457	1.78	1.01	0.000*
	Male	370	2.35	1.30		290	2.28	1.50		360	2.29	1.41	
Segment	Right	430	2.13	1.19	0.195	357	2.10	1.39	0.596	422	2.03	1.25	0.471
	Left	396	2.02	1.17		344	2.05	1.33		395	1.97	1.20	

*$p<0.001$

n: Number of teeth, F: Female, M: Male, MT: Membrane thickness, PBL: Periodontal bone loss, Std: Standard deviation

Table 3 Relationships between periodontal bone loss, age, gender, segment

Parameter		Premolar PBL				I. Molar PBL				II. Molar PBL			
		n	PBL (mm)	Std.	*p*	*n*	PBL (mm)	Std.	*p*	*n*	PBL (mm)	Std.	*p*
Age	Group I	341	1.62	0.72	0.000*	327	1.55	0.77	0.000*	348	1.35	0.73	0.000*
	Group II	208	2.36	1.23		165	2.28	1.31		212	2.08	1.08	
	Group III	240	3.08	1.43		191	3.42	1.90		230	3.08	1.60	
	Group IV	37	3.80	1.19		18	3.85	1.44		27	4.22	1.48	
Gender	Female	456	2.07	1.14	0.000*	411	2.10	1.41	0.000*	457	1.85	1.20	0.000*
	Male	370	2.65	1.43		290	2.57	1.68		360	2.47	1.56	
Segment	Right	430	2.42	1.32	0.049**	357	2.31	1.54	0.687	422	2.16	1.41	0.343
	Left	396	2.24	1.30		344	2.27	1.55		395	2.07	1.39	

*$p < 0.001$

**$p < 0.05$

n: Number of teeth, F: Female, M: Male, MT: Membrane thickness, PBL: Periodontal bone loss, Std: Standard deviation

[4, 21, 33]. The prevalence of MT and PBL was found to be greater in men by Sheikhi et al. [15]. It has been shown by Lu et al. [16] that the rate of MT increases in patient groups over the age of 60. In the study by Göller-Bulut et al. [3] evaluating the relationship between MT and PBL and periapical lesions, it was found that there was more membrane thickening in patients in the 41–60 age group. In the study conducted by Phothikhun et al. [4], the prevalence of membrane thickening was greater in men and in the older age group (>49 years). Conversely, Rege et al. [34] reported that MT was greater in men but was not related to age. Janner et al. [7] reported that gender was the only parameter affecting MT, whereas Zhang et al. [32] reported that gender was not related to MT.

Exposure to environmental and systemic factors for a longer period of time throughout life can be the reason for the increase in age-related membrane thickening. The increase in the extent of pneumatization in the maxillary sinus with advancing age can facilitate the transmission of infection from the porous maxillary bone to the maxillary sinus. Different results in previous studies may be attributed to the lack of consistency in case selection criteria and case standardization.

This study did not examine various factors that may influence sinus MT, such as gingival phenotype and air quality. Studies evaluating the effect of gingival phenotype on MT have identified a positive correlation between gingival phenotype and sinus MT [35, 36]. Another study, however, found a weak correlation between MT and gingival phenotype, and gingival phenotype determined that gingival phenotype was not a reliable predictor of maxillary sinus MT [37]. CBCT imaging of the maxillary sinus has been established as the most reliable method for determining MT [37]. Given the retrospective design of our study, the contribution of PBL to MT can be substantiated by the current results, with our determined exclusion criteria without considering clinical factors. However, future studies should investigate the impact of these potential confounding factors in greater detail, including clinical and radiographic evaluation.

The findings of our study underscore the significant role of periodontal infections in contributing to maxillary sinusitis, highlighting how these infections can lead to sinus membrane thickening even in asymptomatic individuals. This insight is crucial for dental practitioners, as it suggests that treating periodontal disease may not only improve oral health but also mitigate the risk of developing sinus-related complications. While there is a significant likehood of MT decreasing following the extraction of teeth afflicted by periodontitis, this reduction may not always be complete or swift [38]. In some instances, mucosal thickening might become chronic or necessitate further treatment. Early intervention in periodontal disease could therefore be a preventative strategy against

Table 4 Relationships between maxillary sinus membrane thickness and periodontal bone loss, age, and gender

			Anterior MT/Premolar				Median MT/I. Molar				Posterior MT/II. Molar			
Age	**Gender**	**MT**	***n***	**PBL (mm)**	**Std.**	***p***	***n***	**PBL (mm)**	**Std.**	***p***	***n***	**PBL (mm)**	**Std.**	***p***
Group I	F	Class I	135	1.27	0.39	0.000*	122	1.12	0.37	0.021**	151	0.98	0.33	0.432
		Class II	44	1.74	0.57		51	1.74	0.55		39	1.73	0.58	
		Class III	23	2.72	0.66		26	2.92	0.78		17	2.53	0.87	
	M	Class I	67	1.23	0.37	0.002**	68	1.21	0.46	0.026**	82	1.13	0.5	0.248
		Class II	42	1.89	0.64		45	1.78	0.6		42	1.67	0.66	
		Class III	30	2.72	0.65		15	2.91	0.59		17	2.82	0.79	
Group II	F	Class I	28	1.29	0.59	0.415	23	1.35	0.92	0.369	34	1.18	0.63	0.996
		Class II	42	1.76	0.63		39	1.76	0.66		48	1.55	0.6	
		Class III	41	2.75	0.99		31	2.76	1.05		28	2.93	0.88	
		Class IV	2	6.23	2.22		2	6.51	3.26		3	5.27	0.69	
	M	Class I	12	1.41	0.65	0.013**	9	1.42	0.77	0.132	13	1.31	0.79	0.161
		Class II	29	1.99	0.83		29	1.82	0.52		45	1.88	0.68	
		Class III	51	3.18	0.97		30	3.32	1.05		41	3.08	0.81	
		Class IV	3	5.98	0.63		2	6.42	2.56		-	-	-	
Group III	F	Class I	13	1.5	0.45	0.112	9	1.63	0.61	0.228	19	1.37	0.69	0.156
		Class II	45	1.91	0.62		31	2.05	0.67		37	1.9	0.63	
		Class III	53	3.03	0.8		52	3	0.71		57	2.93	0.7	
		Class IV	13	5.42	0.74		12	5.2	1.26		11	5.63	1.74	
		Class V	-	-	-		2	12.36	1.51		-	-	-	
	M	Class I	-	-	-	0.061	5	2.34	0.48	0.124	4	2.34	0.33	0.133
		Class II	20	1.95	0.68		11	2.06	0.89		20	2.14	0.81	
		Class III	69	3.2	0.86		42	3.18	0.87		52	3.1	0.99	
		Class IV	27	5.29	1.36		27	6.11	1.64		30	5.65	1.24	
Group IV	F	Class I	1	3.02	-	0.631	-	-	-	0.808	-	-	-	0.798
		Class II	1	2.6	-		1	2.2	-		1	1.8	-	
		Class III	11	3.38	0.62		4	2.84	0.49		8	3.32	0.3	
		Class IV	4	4.57	0.26		6	4.82	0.71		4	4.66	0.63	
	M	Class I	1	1	-	0.844	-	-	-	0.854	-	-	-	0.964
		Class II	2	1.74	0.13		-	-	-		2	2.27	0.09	
		Class III	5	3.26	0.2		5	2.81	0.3		4	3.45	0.46	
		Class IV	12	4.9	0.85		2	6.4	0.85		8	6.07	0.75	

*$p < 0.001$

**$p < 0.05$

n: Number of teeth, F: Female, M: Male, MT: Membrane thickness, PBL: Periodontal bone loss, Std: Standard deviation sinusitis, emphasizing the need for comprehensive dental assessments in routine check-ups. Various studies assessing MT after tooth extraction has indicated decreases at 2.8, 4, and 12 months, with no further decrease observed afterwards [13, 38, 39]. This indicates that in certain patients, the sinus mucosa does not fully revert to its normal condition. Also, MT can appear not just in teeth with periodontal disease but in the sinus membrane adjacent to these teeth, indicating that periodontal disease can also influence the success of surgical procedures in nearby regions [38]. All these factors can extend the time before implant insertion. Particularly in cases expecting simultaneous tooth extraction, sinus lift, and implant treatment, delays may occur. If MT does not completely normalize post-extraction, risks of infection and implant failure could escalate.

A thickened sinus membrane may enhance the risk of complications during sinus floor augmentation. Carmeli et al. [40] found that the risk of sinus obstruction escalates as the thickness of the sinus mucosa increases; the prevalence of sinus obstruction was 11.1%, 36.2%, and 74.3% in instances where the MT was < 5 mm, 5–10 mm, and > 10 mm, respectively. When the MT and perforation rate were assessed in transrestal sinus lift surgery, evidence indicated the risk of perforation doubled or tripled with a Schneiderian membrane thicker than 3 mm [41]. Sinus perforation could cause the spread and contamination of the graft material into the sinus cavity. Such perforations might complicate sinus floor augmentation and possibly prevent the implant from receiving adequate bone support, negatively impacting its stabilization. A 2018 meta-analysis indicated that intraoperative sinus membrane perforation could enhance the risk of implant failure after sinus floor augmentation [42]. This relationship might be due to spread of graft material in large perforations and resultant inflammation, potentially causing graft and implant loss. Furthermore, the extent of perforation might cause implant placement to be delayed [7]. The perforation could allow bacteria to infiltrate the sinus cavity, raising the risk of infection [41]. Postoperative edema, coupled with a thickened sinus membrane, might block the ostium, potentially leading to drainage disorders and sinusitis [43]. Given these findings, the study emphasizes the importance of early intervention in periodontal disease to reduce the risk of sinus-related complications and maximize treatment outcomes in dental implant procedures. In addition, radiographic evaluation with CBCT in patients planned for augmentation surgery is also important for successful treatment.

In this study, PBL was only measured on the buccal and palatal surfaces of the teeth without evaluating PBL in the furcation area and residual bone height. Existing literature reports suggest that PBL and residual bone height can influence MT, whereas bone resorption in the furcation area does not seem to relate to MT [32, 36, 44]. The data suggests that an increase in PBL might heighten the severity of the MT [44]. Inflammation stemming from periodontal disease can affect the maxillary sinus in various ways. The disease may cause local inflammation or direct bacterial invasion, impacting the sinus membrane. Even when the roots of the maxillary posterior teeth maintain a certain distance from the maxillary sinus, the porous structure of the alveolar bone and irregularities in the cortical bone plate of the maxillary sinus floor, combined with micropores, may facilitate bacterial spread into the maxillary sinus [13, 44]. Moreover, the identification of periodontal pathogenic bacteria known to cause periodontitis in infections related to the maxillary sinus indicates a possibility of periodontal inflammation reaching the sinus, thus causing further inflammation [12]. Future studies, investigating any potential link between PBL in the furcation area, residual bone height, and MT could provide a more comprehensive understanding of the mechanisms leading membrane thickening mechanisms.

This study's retrospective design and reliance on CBCT scans without accompanying clinical examinations introduce inherent limitations. A primary limitation of this study arises from the difficulty in obtaining detailed records of periodontal and sinus issues solely through retrospective CBCT scans. The lack of a true control group (subjects with no signs of periodontal pathology in their posterior teeth on clinical examination and no clinical signs of acute sinusitis) may affect the generalizability of our findings. Therefore, when pathological images are excluded, the existence of sinus pathologies cannot be disregarded entirely in these subjects. Although teeth with periapical lesion imagery were excluded from the measured areas, endodontic problems may not be entirely eliminated as specific data could not be collected through clinical examination (e.g., percussion sensitivity, vitality test, probing depth measurement, and instrumental x-rays from the periodontal pocket). Our inability to obtain sufficient clinical data regarding the periodontal status of the individuals whose images were scanned resulted in the inability to detect changes in MT values in periodontally treated and untreated individuals. Additionally, the effects of periodontal treatment on the success of MT-related factors (such as sinus augmentation success, implant survival, radiological bone gain, and reduction in patient symptoms) could not be directly evaluated. This may explain why the effect of MT on periodontal treatment cannot be determined precisely. However, the exclusion of pathological regions in CBCT scans may result in the data representing only asymptomatic individuals. Future studies should aim to incorporate clinical assessments to validate the radiographic indicators of periodontal disease and sinus pathology.

Additionally, prospective studies could provide more definitive evidence of the causal relationships suggested by our findings.

Conclusions

Our study revealed a significant increase in maxillary sinus MT in individuals with PBL. This finding suggests that progressive and untreated periodontal disease may be associated with maxillary sinus infections. It is expected that future clinical, histopathological, and microbiological studies will make the thickening and change mechanisms of the maxillary sinus membrane more understandable. Additional research may be an important guide for the development of more effective treatment strategies and successful implant procedures. This information can contribute to the development of clinical decisions and treatment plans in implantology practices.

Abbreviations

CBCT Cone beam computed tomography
CEJ Cemento-enamel junction
MT Membrane thickness
PBL Periodontal bone loss

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Author contributions
C.E. and B.Ş. conceived and designed the study. C.E. completed the data collection. C.E. and B.Ş. analyzed the data. C.E. wrote the paper. C.E. reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

Declarations

Ethics approval and consent to participate
This study was approved by the "Non-Interventional Clinical Research Ethics Committee" of the Eskişehir Osmangazi University; Eskişehir, Turkey; under the reference number: 2020-29 (issue date: 14.07.2020). Patients who provided written informed consent were included in the study. The authors confirm that research was performed in full accordance with the regulations and guidelines of the "World Medical Association Declaration of Helsinki in 2013".

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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