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Evaluation of the relationship between periodontal bone loss and Schneiderian membrane thickness in upper posterior teeth with root tips associated with the maxillary sinus: a retrospective cone beam computed tomography study

Kevser Sökmen[1*] and Nurullah Sökmen[2]

Abstract

Background This study aimed to examine the effects of periodontal bone loss (PBL) in upper posterior teeth with root tips in contact with the maxillary sinus on sinus mucosal thickening (SMT) via cone beam computed tomography (CBCT).

Methods One hundred sixty CBCT images were divided into four equal groups according to the season in which they were taken: spring, summer, autumn, and winter ($n=40$). The relationships among sex, age, PBL, and SMT were evaluated. SMT was measured at the site with the greatest distance from the sinus base to the upper edge of the sinus mucosa. SMT exceeding 2 mm was considered pathological. The SMT value was categorized into four classes (Class I: <2 mm, Class II: 2.1–5 mm, Class III: 5.1–10 mm, and Class IV: >10 mm). The PBL level was determined by measuring the distance between the point located 2 mm apical to the cemento-enamel level and the upper border point of the alveolar bone. PBL was calculated by dividing this value by the distance between the apex of the longest root and the point located 2 mm apical to the cemento-enamel border and multiplying by 100. PBL was categorized into three classes (Type I: 25%, Type II: 25–50%, Type III: >50% bone loss).

Results No statistically significant relationships were found among sex, season during which the image was taken, the side of the maxillary sinus (right or left) and SMT ($p>0.05$). The percentage of Class IV SMT in individuals over 50 years of age (41.9%) was statistically significantly greater than that in other age groups ($p<0.05$). The percentage of Class IV SMT in individuals with severe PBL (60.7%) was significantly greater than that in individuals with mild (0%) and moderate (3.2%) PBL ($p<0.05$).

*Correspondence:
Kevser Sökmen
kevser.sokmen@alanya.edu.tr

Full list of author information is available at the end of the article

Conclusions Age and PBL were significantly associated with SMT. As the periodontitis grade (PBL/age) increases, SMT gradually increases.

Keywords Cone beam computed tomography, Periodontal bone loss, Sinus mucosal thickening, Season

Introduction

The maxillary sinus is the largest cavity located bilaterally within the maxillary bone. This pyramid-shaped space, which reaches its maximum size between 18 and 20 years of age, is covered by the Schneiderian membrane [1, 2]. The most frequent pathological condition in the maxillary sinuses is thickening of the Schneiderian mucosal membrane; its typical thickness is approximately 1 mm, and thickening exceeding 2 mm is considered pathological [3]. This increased thickness is observed in the presence of systemic or local factors such as infections, trauma, tumoral changes, foreign body reactions, allergies, and asthma [4].

It has been reported that, among all tooth root tips, those of the maxillary first and second molars are in closest contact with the maxillary sinus floor. It has been reported that the root tips of the maxillary second premolar teeth also frequently show these contacts [5]. Given this close relationship, periapical infection of dental origin can lead to maxillary sinus mucosal thickening (SMT); however, the effect of periodontal infection on SMT remains uncertain [6].

It has been reported that demographic changes in individuals and seasonal changes are other factors affecting SMT [7, 8]. Although some studies have indicated that sex is the only factor affecting SMT and that it is more common in men [9, 10], others have demonstrated that age also plays a major role [7, 11]. Likewise, some studies have demonstrated that seasonal changes affect SMT, whereas others have found no association [7, 8].

Cone beam computed tomography (CBCT) is a reliable method used to examine structures in the maxillofacial region, such as the maxillary sinus, alveolar bone, periodontal, and periapical situations, by taking multiple sections in different planes [12]. The dimensions of the sections used in CBCT are as small as 0.125 mm, preventing possible pathologies from being overlooked; thus, CBCT is the most effective method for diagnosis and treatment planning in dentistry [13].

Since studies have not reached a full consensus on which is the most effective factor affecting SMT, this issue continues to be a subject of research in the literature. Therefore, our aim in this study was to retrospectively examine the effects of PBL in upper posterior teeth, whose root tip is in contact with the maxillary sinus, demographic changes, and season on SMT in CBCT images.

Materials and methods

Study samples

This retrospective study was approved by the Alanya Alaaddin Keykubat University Clinical Research Ethics Committee on February 15, 2023, with reference numbers 2–10.

CBCT images were obtained from the CBCT archive of patients who visited Alanya Oral and Dental Health Center Hospital for dental treatments between 2019 and 2023, required radiographic imaging, and had a history of periodontitis. The study aims and scope were explained in detail to the included participants, and written informed consent was obtained from each participant. The study was conducted in compliance with the tenets of the Declaration of Helsinki.

The study included maxillary 2nd premolars and 1st and 2nd molars with 1 or more roots, the tips of which were in contact with the maxillary sinus membrane (in contact) or projected toward the sinus and SMT (related to the maxillary sinus). A total of 160 maxillary sinus CBCT images met the inclusion criteria and were arranged into 4 equal groups according to the season in which they were taken (spring, summer, autumn, and winter ($n = 40$)); furthermore, the images were also evaluated according to whether the SMT was on the right or left side.

Inclusion and exclusion criteria

The inclusion criteria were that the patient had a history of periodontitis, all upper jaw posterior teeth were in the mouth, the root tip was fully covered, it was free of decay, it had not received restorative or endodontic treatment, there was no periapical lesion, the maxillary sinus was clearly visualized, and there was an SMT. Being under 18 years of age, smoking, upper respiratory tract diseases such as asthma, COPD, allergies, sinusitis, periodontal surgery in the upper posterior region, history of maxillary sinus surgery, trauma or pathological formation (e.g., cysts, tumors) in the maxillary region, edentulous in the maxillary posterior region or having caries, fillings, root canal fillings, periapical lesions or prosthetic restorations on maxillary posterior teeth and poor CBCT image quality was determined as the exclusion criteria.

CBCT image analysis

CBCT images evaluated in the study were acquired with a tomography device (Planmeca® Promax 3D Mid, Helsinki, Finland; 90 kVp, 6.3 mA) located at Alanya Oral and Dental Health Center Hospital. Owing to the head

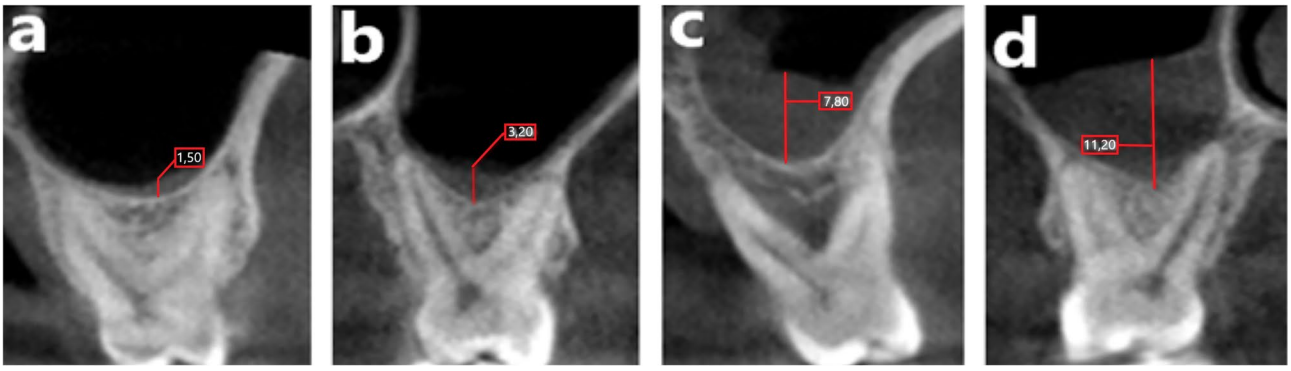

Fig. 1 CBCT images showing the sinus mucosal thickness value. a Class I (<2CBCT images showing the sinus mucosal thickness value. **a** Class I (<2 mm) **b** Class II (2.1–5 mm) **c** Class III (5.1–10 mm) **d** Class IV (>10 mm). Note: The red line indicates the site of sinus mucosal thickness measurement
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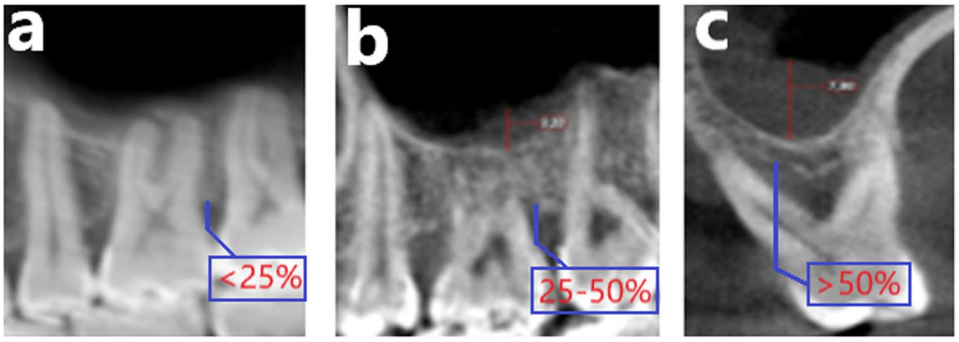

Fig. 2 CBCT images showing the level of periodontal bone loss. **a** Class I (normal to mild, <25% bone loss) **b** Class II (moderate, 25–50% bone loss) **c** Class III (severe, >50% bone loss) Note: The blue line indicates the level of periodontal bone loss
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stabilizers of this tomography device, images obtained in standard patient positions during imaging were archived. The archived patient records were reviewed via the computer program I-Dixel V 1.1.6.4 (J. Morita MFG CORP, Kyoto, Japan). To evaluate SMT and PBL, we examined each CBCT image in three planes: coronal, axial, and sagittal. All CBCT image measurements were performed by a calibrated investigator (KS). A red dot was placed on the cross-sectional CBCT image for measurement, and measurements were recorded and subsequently deleted. Another researcher (NS) repeated the measurements on this red-dotted CBCT slice on the same computer at different times to prevent measurement errors. Cases with different measurement values were excluded from the study.

Sinus mucosal thickness assessment

Coronal section CBCT images were used for SMT measurement. Mucosal thickness was measured per sinus at the site with the greatest distance from the sinus base to the upper edge of the sinus mucosa. SMT exceeding 2 mm was considered pathological. The SMT value was categorized into four classes (Fig. 1) [14]:

Class I: <2 mm.
Class II: 2.1–5 mm.
Class III: 5.1–10 mm.
Class IV: >10 mm.

Evaluation of periodontal bone loss

PBL was determined on CBCT images by measuring the distance between the point located 2 mm apical to the cemento-enamel level and the upper border point of the alveolar bone. PBL was calculated by dividing this value by the distance between the apex of the longest root and the point located 2 mm apical to the cemento-enamel border and multiplying by 100. PBL was categorized into three classes (Fig. 2) [15]:

Type I (Mild): <25% bone loss.
Type II (Moderate): 25–50% bone loss.
Type III (Severe): >50% bone loss.

If PBL was present at different degrees in several areas of a tooth in an arch or in two or more teeth in an arch, the most severe class was considered.

Evaluation of periodontitis grade

The periodontitis grade was calculated by dividing the percentage of periodontal bone loss by the patient's age. PBL/age was divided into three classes according to the 2017 Classification of Periodontal and Peri-Implant Diseases and Conditions by the American Academy of Periodontology (AAP) [16]:

Grade A (Slow rate of progression): <0.25.
Grade B (Moderate rate of progression): 0.25-1.
Grade C (Rapid rate of progression): >1.

Evaluation of demographic changes

Patients were grouped according to sex, age, and whether they were in the right or left maxillary sinus, and their effects on SMT were evaluated.

The patients were divided into 3 groups by age [17]:
Group I: Under 25 years.
Group II: 25–50 years.
Group III: Over 50 years.

Statistical analysis

The IBM SPSS Statistics 22 program was used for the statistical analyses. In addition to descriptive statistical methods (frequency), the chi-square test was used to compare qualitative data. Additionally, scatter analysis was performed to graphically demonstrate the nature of the relationship between PBL and SMT. Significance was evaluated at the $p < 0.05$ level.

The G*Power 3.1.9.4 (Franz Faul, Universität Kiel, Kiel, Germany) package program was used to calculate the sample size. In the power analysis, the sample size for the four groups was calculated as 148, with an effect size of 0.35, a significance level of $\alpha = 0.05$, and 95% power. However, considering the possibility of missing data and sampling error, the study was planned to be conducted with a larger population than expected, $n = 40$ for each group, 160 in total. No potential loss or measurement error occurred during the study and all data ($n = 40$ for each group, 160 in total) were included in the study.

Results

The study included 160 patients, 79 (49.4%) men and 81 (50.6%) women; 24.4% were under 25 years of age, 56.3% between 25 and 50, and 19.4% over 50. SMT was on the right side in 53.1% of the patients and on the left in 46.9%. Regarding SMT class, 20% of the patients had Class I, 30% had Class II, 27.5% had Class III, and 22.5% were Class IV. Mild, moderate, and severe PBL was present in 26.3%, 38.7%, and 35% of the patients, respectively. The distributions of sinus mucosal thickness according to class, sex, age, and season are shown in Table 1.

Table 1 Evaluation of the distribution of sinus mucosal thickness according to sex, age and season

	Sinus Mucosal Thickness																	
	Class I				Class II				Class III				Class IV					
	Mean (mm)	Standard Deviation (SD)	95% Confidence Interval (±)	Min.(mm)	Max. (mm)	Mean (mm)	Standard Deviation (SD)	95% Confidence Interval (±)	Min. (mm)	Max. (mm)	Mean (mm)	Standard Deviation (SD)	95% Confidence Interval (±)	Min. (mm)	Max. (mm)	Mean (mm)	Standard Deviation (SD)	95% Confidence Interval (±)	Min. (mm)	Max. (mm)
Sinus mucosal thickness	1.50	0.30	±0.11	0.5	1.9	3.60	0.80	±0.23	2.1	5.0	7.10	1.20	±0.36	5.2	9.8	11.25	0.58	±0.20	10.1	12.4
Sex Female	1.50	0.26	±0.15	0.54	1.88	3.61	0.79	±0.27	2.16	4.95	7.13	1.20	±0.39	5.11	9.99	11.20	0.55	±0.32	10.10	12.30
Male	1.46	0.28	±0.13	0.52	1.89	3.55	0.74	±0.22	2.14	4.98	7.10	1.16	±0.38	5.12	9.96	11.35	0.52	±0.23	10.30	12.40
Age <25	1.48	0.25	±0.14	0.52	1.89	3.54	0.73	±0.25	2.15	4.93	7.02	1.10	±0.40	5.14	9.91	11.10	0.40	±3.59	10.30	11.90
25-50	1.51	0.27	±0.15	0.54	1.88	3.63	0.77	±0.21	2.18	4.96	7.19	1.23	±0.38	5.10	9.98	11.05	0.48	±0.40	10.10	12.00
>50	1.52	0.29	±0.16	0.56	1.90	3.67	0.79	±0.22	2.20	4.97	7.25	1.18	±0.37	5.11	9.99	11.50	0.45	±0.27	10.60	12.40
Season Spring	1.46	0.26	±0.14	0.54	1.88	3.59	0.75	±0.28	2.17	4.98	7.05	1.19	±0.42	5.11	9.97	11.45	0.48	±1.19	10.50	12.40
Summer	1.49	0.28	±0.13	0.55	1.87	3.56	0.72	±0.24	2.15	4.95	7.11	1.22	±0.41	5.14	9.99	10.80	0.35	±3.14	10.10	11.50
Autumn	1.52	0.29	±0.12	0.57	1.90	3.64	0.78	±0.25	2.20	4.96	7.20	1.15	±0.35	5.13	9.96	11.30	0.35	±0.87	10.60	12.00
Winter	1.53	0.30	±0.11	0.58	1.91	3.62	0.76	±0.27	2.18	4.94	7.18	1.18	±0.37	5.10	9.93	11.20	0.45	±0.30	10.30	12.10

From: The effect of periodontal status on the thickness of the Schneiderian membrane in upper posterior teeth with root tip associated with the maxillary sinus: A retrospective cone beam computed tomography study

Mucosal thickness

There was no statistically significant difference between men and women in terms of right, left, and total SMT ($p > 0.05$) (Table 2).

There was a statistically significant difference between age groups in terms of right, left, and total SMT ($p < 0.05$). The rates of Class I right, left, and total SMT in patients under 25 years of age were significantly greater than those in patients between 25 and 50 and over 50 years of age ($p < 0.05$). The rates of Class III and Class IV right SMT in patients over 50 years of age were significantly greater than those in patients under 25 years of age ($p < 0.05$). The rates of Class III total SMT in those aged 25–50 years and over 50 years were significantly greater than those in patients under 25 years ($p < 0.05$). The rates of Class IV left and total SMT in patients over 50 years of age were significantly greater than those in patients under 25 years of age and those between 25 and 50 years of age ($p < 0.05$). In addition, the rate of Class IV total SMT among those aged 25–50 years (22.2%) was significantly greater than that among those under 25 years of age (7.7%) ($p < 0.05$) (Table 2).

There was no statistically significant difference in terms of right, left, and total SMT between seasons ($p > 0.05$) (Table 2).

Periodontal bone loss

There was no statistically significant difference in PBL between men and women ($p > 0.05$) (Table 3).

There was a statistically significant difference in PBL between age groups ($p < 0.05$). The rate of mild PBL in patients under 25 years of age was significantly greater than that in patients between 25 and 50 years of age and over 50 years of age ($p < 0.05$). Additionally, the rate of mild PBL between the ages of 25 and 50 years was significantly greater than that in patients over the age of 50 years ($p < 0.05$). The rates of severe PBL in patients over the age of 50 years were significantly greater than those in patients under the age of 25 years and those between the ages of 25 and 50 years ($p < 0.05$). Additionally, the rate of severe PBL in patients between the ages of 25 and 50 years was significantly greater than that in those under the age of 25 years ($p < 0.05$) (Table 3).

There was no statistically significant difference in PBL between the right and left sides ($p > 0.05$) (Table 3).

Effect of periodontal bone loss on mucosal thickness

There was a statistically significant relationship between PBL and SMT ($p < 0.05$). The rate of Class I SMT in patients with mild PBL was significantly greater than that in patients with moderate and severe PBL ($p < 0.05$). The rate of Class II SMT in patients with moderate PBL was significantly greater than that in patients with mild and severe PBL ($p < 0.05$). The rate of Class III SMT in patients with moderate and severe PBL was significantly greater than that in patients with mild PBL ($p < 0.05$). The rate of Class IV SMT in patients with severe PBL was significantly greater than that in patients with mild and moderate PBL ($p < 0.05$) (Table 4). The scatter plot showing the relationship between PBL and SMT is shown in Fig. 3.

Effect of periodontitis grade on mucosal thickness

There was a statistically significant relationship between SMT and periodontitis grade based on the PBL/age ratio ($p < 0.05$). The rate of Class I SMT in patients with Grade A periodontitis was significantly greater than that in patients with Grade B and Grade C ($p < 0.05$). The rate of Class II SMT in patients with Grade B periodontitis was significantly greater than that in patients with Grade A and Grade C ($p < 0.05$). The rate of Class III SMT in patients with Grade B and Grade C periodontitis was significantly greater than that in patients with Grade A ($p < 0.05$). The rate of Class IV SMT in patients with Grade C periodontitis was significantly greater than that in patients with Grade A and Grade B ($p < 0.05$) (Table 5).

Discussion

There are many studies investigating the effects of periodontal diseases on SMT [17, 18]. However, these studies have many limitations, as they do not simultaneously determine factors such as a history of periodontitis, the presence of all upper posterior teeth in the mouth, root tips being related to the sinus, no restoration, no periapical lesion, and seasonal change as inclusion criteria. Therefore, our aim in this study is to investigate the effects of PBL, demographic changes, and season on SMT in upper posterior teeth with a history of periodontitis, root tip is in contact with the maxillary sinus, which has not received restorative or endodontic treatment and does not have periapical lesions. In light of the data obtained from our study, it was found that SMT was associated with age and PBL.

Maxillary sinuses begin to form in the 12th week of intrauterine life and their development accelerates with birth. They reach their maximum size at approximately 18–20 years of age [1]. Thus, we included individuals over 18 with fully developed maxillary sinuses in our study to yield more reliable results.

In their study of 194 CBCT images, Zhang et al. reported no statistically significant difference in SMT between males and females [19]. Similarly, in their study of 600 maxillary sinus CBCT images, Ince Yusufoğlu et al. reported that no significant relationship was observed between sex and SMT [20]. On the other hand, in their study, where they evaluated CBCT images of 235 patients, Huang et al. argued that SMT was more common in males than in females [18]. In their study on 100

Table 2 Evaluation of sinus mucosal thickness according to sex, age and season

		Right sinus mucosal thickness				Left sinus mucosal thickness				Total sinus mucosal thickness			
		Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Sex	Male	8 (20)	11 (27.5)	7 (17.5)	14 (35)	5 (12.8)	14 (35.9)	12 (30.8)	8 (20.5)	13 (16.5)	25 (31.6)	19 (24.1)	22 (27.8)
	Female	11 (24.4)	16 (35.6)	12 (26.7)	6 (13.3)	8 (22.2)	7 (19.4)	13 (36.1)	8 (22.2)	19 (23.5)	23 (28.4)	25 (30.9)	14 (17.3)
	*p**	0.130				0.399				0.286			
Age	<25	10 (45.5)	9 (40.9)	1 (4.5)	2 (9.1)	8 (47.1)	4 (23.5)	4 (23.5)	1 (5.9)	18 (46.2)	13 (33.3)	5 (12.8)	3 (7.7)
	25-50	8 (18.2)	15 (34.1)	10 (22.7)	11 (25)	5 (10.9)	15 (32.6)	17 (37)	9 (19.6)	13 (14.4)	30 (33.3)	27 (30)	20 (22.2)
	>50	1 (5.3)	3 (15.8)	8 (42.1)	7 (36.8)	0 (0)	2 (16.7)	4 (33.3)	6 (50)	1 (3.2)	5 (16.1)	12 (38.7)	13 (41.9)
	*p**	0.003*				0.003*				0.001*			
Season	Summer	4 (23.5)	5 (29.4)	2 (11.8)	6 (35.3)	5 (21.7)	10 (43.5)	4 (17.4)	4 (17.4)	9 (22.5)	15 (37.5)	6 (15)	10 (25)
	Spring	3 (12.5)	4 (16.7)	9 (37.5)	8 (33.3)	3 (18.8)	2 (12.5)	5 (31.3)	6 (37.5)	6 (15)	6 (15)	14 (35)	14 (35)
	Winter	6 (27.3)	10 (45.5)	2 (9.1)	4 (18.2)	3 (16.7)	2 (11.1)	8 (44.4)	5 (27.8)	9 (22.5)	12 (30)	10 (25)	9 (22.5)
	Autumn	6 (27.3)	8 (36.4)	6 (27.3)	2 (9.1)	2 (11.1)	7 (38.9)	8 (44.4)	1 (5.6)	8 (20)	15 (37.5)	14 (35)	3 (7.5)
	*p**	0.115				0.112				0.064			

Chi-square Test

*Statically significant ($p < 0.05$)

From: The effect of periodontal status on the thickness of the Schneiderian membrane in upper posterior teeth with root tip associated with the maxillary sinus: A retrospective cone beam computed tomography study

maxillary sinus CBCT images, Al-Bahrani et al. reported that SMT > 6 mm is more common in male versus female individuals [21]. In our study, no statistically significant difference in SMT was found between males and females, which is consistent with the study of Zhang et al. and Ince Yusufoğlu et al. We believe that the disparity in findings results from patient selection criteria. In our study, patients who smoked and teeth whose root tips were not in contact with the maxillary sinus were not included. On the other hand, Huang et al. included smokers in their study. Ince Yusufoğlu et al. did not seek the criterion of the root tip of the upper posterior teeth being in relationship with the maxillary sinus in their study.

Lathiya et al. examined 140 maxillary sinus CBCT images, revealing a significant relationship between age and SMT, with SMT encountered more frequently in older individuals [22]. In their study, where they evaluated 235 maxillary sinus CBCT images, Huang et al. showed that the risk of SMT increased 4.35 times in older individuals compared to younger individuals [18]. On the other hand, Goller-Bulut et al. showed in their study that SMT prevalence was higher in individuals aged 41–60 years (middle-aged) [23]. Ren et al. reported that the prevalence of SMT increased in patients between the ages of 26 and 40 years and decreased thereafter [24]. In their study, where they evaluated CBCT images of 141 patients, Akbari et al. reported that age was not a factor related to SMT [25]. In our study, the rate of Class IV SMT in older individuals was statistically significantly greater than that in other age groups, consistent with the studies of Lathiya et al. and Huang et al. We believe that the differences in our results from those reported in other studies result from the unequal number of samples across different age groups in prior studies.

In their study, where they evaluated CBCT images of 144 patients, Zimmo et al. reported that seasonal changes were not an effective factor on SMT [7]. Similarly, Schneider et al. reported no statistical difference in SMT between seasons [26]. Khojastepour et al. reported that SMT was more common in winter [27]. In our study, no statistically significant difference was found between seasons in terms of right, left, and total SMT. Although our results align with earlier studies, they contradict the study of Khojastepour et al. We believe that this disparity is due to the mild winter months in the Alanya and Antalya regions, where CBCT images were taken. Additionally, excluding individuals with a history of allergies or acute or chronic sinusitis may have resulted in these contradictory findings.

Zhang et al. evaluated alveolar bone size and morphology by CBCT in 90 patients diagnosed with periodontitis and reported that sex was a factor that did not affect the degree and distribution of PBL [19]. In their study investigating the prevalence of periodontal-related tooth loss

Table 3 Evaluation of periodontal bone loss by sex, age and side

Periodontal bone loss	Sex		Age			Side	
	Male	Female	< 25	25–50	> 50	Right	Left
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Mild (< 25%)	18 (22.8)	24 (29.6)	24 (61.5)	17 (18.9)	1 (3.2)	25 (29.4)	17 (22.7)
Moderate (25–50%)	29 (36.7)	33 (40.7)	13 (33.3)	40 (44.4)	9 (29)	30 (35.3)	32 (42.7)
Severe (> 50%)	32 (40.5)	24 (29.6)	2 (5.1)	33 (36.7)	21 (67.7)	30 (35.3)	26 (34.7)
*p**	0.327		0.001*			0.534	

Chi-square Test

*Statically significant ($p < 0.05$)

From: The effect of periodontal status on the thickness of the Schneiderian membrane in upper posterior teeth with root tip associated with the maxillary sinus: A retrospective cone beam computed tomography study

Table 4 Evaluation of sinus mucosal thickness according to periodontal bone loss

Sinus mucosal thickness	Periodontal bone loss		
	Mild (< 25%)	Moderate (25-50%)	Severe (> 50%)
	n (%)	*n* (%)	*n* (%)
Class I	31 (73.8)	1 (1.6)	0 (0)
Class II	11 (26.2)	34 (54.8)	3 (5.4)
Class III	0 (0)	25 (40.3)	19 (33.9)
Class IV	0 (0)	2 (3.2)	34 (60.7)
*p**		0.001*	

Chi-square Test

*Statically significant ($p < 0.05$)

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Table 5 Evaluation of sinus mucosal thickness according to periodontitis grade

Sinus mucosal thickness	Periodontitis grade (Periodontal bone loss/age)		
	Grade A (< 0.25)	Grade B (0.25-1.0)	Grade C (> 1.0)
	n (%)	*n* (%)	*n* (%)
Class I	17 (70.8)	14 (17.5)	1 (1.8)
Class II	7 (29.2)	31 (38.8)	10 (17.9)
Class III	0 (0)	27 (33.8)	17 (30.4)
Class IV	0 (0)	8 (10)	28 (50)
*p**		0.000*	

Chi-square Test

*Statically significant ($p < 0.05$)

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in 93 patients with chronic periodontitis, Karthikeyan Murthykumar et al. reported that sex was not associated with periodontal-related tooth loss [28]. In their study investigating the reliability of CBCT in 202 bone defect areas across 40 patients diagnosed with chronic

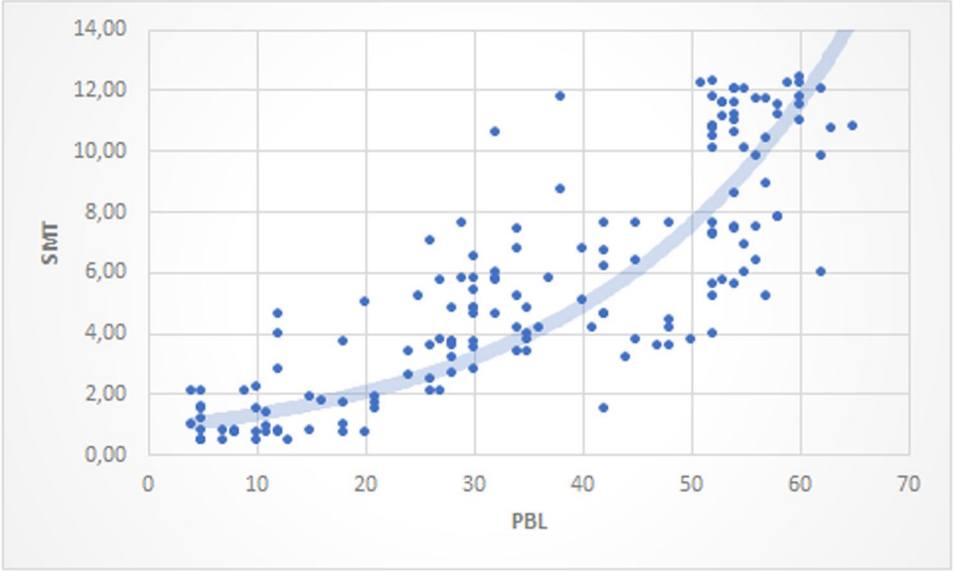

Fig. 3 Scatter plot showing the relationship between periodontal bone loss and sinus mucosa thickness. Note: Each point on the scatter plot graph represents the individual value of sinus mucosal thickness based on the periodontal bone loss measurement
From: The effect of periodontal status on the thickness of the Schneiderian membrane in upper posterior teeth with root tip associated with the maxillary sinus: A retrospective cone beam computed tomography study

periodontitis, Patil et al. found that PBL was more common in males versus females; this difference was attributed to differences in sex hormone levels [29]. In their systematic review investigating sex differences in periodontal disease, Shiau et al. reported that male individuals had a higher prevalence and severity of periodontal disease than female individuals. They explained this situation by the fact that cigarette consumption, which is an important risk factor for periodontal disease, is greater in males than in females [30]. These different results across studies show that the relationship between sex and PBL remains controversial. In our study, no statistically significant difference was found between both sexes in terms of PBL. Our results are consistent with the studies of Zhang et al. and Karthikeyan Murthykumar et al., but contradict the studies of Patil et al. and Shiau et al. The exclusion of smoking patients in our study may have resulted in these contradictory findings.

Periodontitis is a chronic inflammatory disorder caused by subgingival biofilms that destroy the alveolar bone and connective tissue surrounding the tooth [31]. In their study investigating the relationship between probiotic consumption and periodontitis, Ren et al. reported that the severity and prevalence of PBL increased in individuals over 65 years of age, compared to other age groups, with or without probiotic consumption [32]. Similarly, in their study evaluating the prevalence and severity of periodontitis in the Australian population, Bertl et al. reported that the prevalence of PBL increased in older individuals compared with that in younger individuals [33]. In their study evaluating PBL in 1146 patients, Qian et al. reported that the prevalence of PBL increased with advancing age [34]. In our study, severe PBL cases in individuals over the age of 50 years and mild PBL cases in individuals aged 25 years and under were found to be statistically significantly greater than those in other age groups. The results of our study are consistent with those of previous studies. In an evaluation of 716 maxillary sinus CBCT images, Yıldırım et al. reported no significant variation in PBL in the right versus left jaw regions [15]. The fact that there was no statistically significant difference in terms of PBL between the right and left sides in our study is supported by the study of Yıldırım et al.

In a study of 30 patients, Cao et al. investigated the effects of upper posterior teeth requiring due to periodontitis and those not requiring extraction on SMT, reported that the SMT in areas with PBL necessitating extraction was greater than that in areas that did not require extraction. They explained this situation by the spread of pathogenic bacteria and toxins, which cause PBL in teeth with severe periodontitis, into the maxillary sinus [35]. Lathiya et al. investigated the effect of periodontal flap surgery on SMT in 30 patients diagnosed with chronic periodontitis, reporting decreased SMT in CBCT images obtained 9 months after flap surgery [36]. These two studies clearly revealed that PBL affects SMT and that surgical procedures to treat periodontitis improve SMT. Dumitrescu et al. reported that periodontal disease and periapical lesions in the upper posterior teeth affect the maxillary sinus and cause SMT [37]. Therefore, in our study, teeth with periapical lesions were excluded to focus on the relationship between PBL and SMT, preventing periapical lesions from adversely affecting the results. In their study, where they evaluated CBCT images of 72 patients with periodontitis, Song et al. reported that when the severity of PBL in the molar region increased, the SMT increased 6–7 fold [17]. In their study evaluating 194 CBCT images, Zhang et al. reported that the rate of SMT increased as PBL progressed from mild to severe [19]. Similarly, many studies have argued that SMT increases proportionately to PBL severity [18, 24, 38]. In their study, where they evaluated the maxillary sinus CBCT images of 300 patients, Ince Yusufoğlu et al. reported that mild PBL, especially in the upper 6th and 7th teeth, showed a more significant relationship with the incidence of SMT than severe PBL [20]. The results of our study are consistent with those of previous studies; as the severity of PBL increased, SMT also increased. Our study only contradicts the study of Ince Yusufoğlu et al. We believe that this discrepancy is due to the low number of patients with severe PBL included in Ince Yusufoğlu et al.'s study.

In their study evaluating 231 maxillary sinus CBCT images, Veluri et al. classified the severity of periodontal disease into three categories based on the 2017 EFP/AAP classification and reported that the increase in mucosal thickness was proportional to the severity of periodontal disease [39]. Our study is the first study to investigate the effect of periodontitis grade (PBL/age) on sinus mucosal thickness, based on literature reviews. In this study, periodontitis grade (PBL/age) was categorized into three classes according to the 2017 EFP/AAP classification and it was found that sinus mucosal thickness increased with periodontitis grade increased. Ekşi et al., in their study examining maxillary sinus CBCT images of 527 patients, reported that periodontal bone loss was greater in regions with Class IV mucosal thickness, and that both the severity of periodontitis and mucosal thickness increased with age [40]. Similarly, in their study evaluating 235 maxillary sinus CBCT images, Huang et al. reported that sinus mucosal thickness was greater in cases of severe periodontal bone loss and among elderly patients [18]. In their study evaluating 100 maxillary sinus CBCT images, Al-Bahrani et al. reported that Type I sinus mucosal thickness was more frequently observed in the 20–30 age group, whereas Type IV mucosal

thickness was more commonly found in the 31–40 and 41–50 age groups [21]. As understood from these studies, age is an effective factor on both periodontal bone loss and sinus mucosal thickness. Therefore, in our study, we also investigated the effect of periodontitis grade (PBL/age) on mucosal thickness. The finding that sinus mucosal thickness increased significantly in individuals with Grade C periodontitis compared to Grade A and B is consistent with these studies.

In this study, owing to equipment and ethical limitations, the relationship between PBL and SMT was evaluated retrospectively only on CBCT images. As this was a retrospective study, clinical findings such as percussion, palpation, vitality testing, and probing pocket depth measurements in the upper posterior teeth could not be examined. The patients' anamnesis information included only patient statements, representing another limitation. Due to the many limitations in the inclusion criteria, the findings of our study could not be generalized to the wider population, and being limited to 160 CBCT images is also a limitation. Finally, the lack of a true control group (patients without PBL) was a limitation.

Conclusion

On the basis of the limited results of this study, the two main factors that cause an increase in SMT are advancing age and PBL severity. Additionally, as periodontitis grade increases, SMT gradually increases. It is thought that early diagnosis and treatment of periodontal disease will prevent its negative effects on SMT. More comprehensive studies that include clinical, histopathological, and microbiological evaluations of PBL and SMT and evaluations of the effects of periodontal treatment with longer follow-up periods and larger samples are needed to determine the effects of PBL on SMT. It is also thought that examining this issue in coordination with both periodontology specialists and medical specialists will provide additional contributions.

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Authors' contributions
The design of the study, radiological analysis and data collection were carried out by K.S. and N.S. Statistical analysis, interpretation of the data and writing of the article were carried out by K.S. All authors read and approved the final manuscript.

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Data availability
It can be requested from the corresponding author if deemed necessary.

Declarations

Ethics approval and consent to participate
Alaaddin Keykubat University Clinical Research Ethics Committee approved the research protocol with the number 2–10 on 15.02.2023. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee. Informed consent term was obtained from every individual participant included in this study. The study was performed in accordance with the guidelines of the 1964 Helsinki Declaration.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Periodontology, Faculty of Dentistry, Alanya Alaaddin Keykubat University, Konaklı, Alanya, Antalya 07400, Turkey
[2]Alanya Oral and Dental Health Center, Oba, Alanya, Antalya 07400, Turkey

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