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# The Relationship Between Periodontal Bone Loss and Sinus Membrane Thickness: A Cone Beam Computed Tomography-Based Assessment

## Periodontal Kemik Kaybı ile Sinüs Membran Kalınlığı Arasındaki İlişkinin Konik Işınlı Bilgisayarlı Tomografi ile İncelenmesi

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**ABSTRACT Objective:** Sinus membrane thickening exceeding 2 mm is considered a pathological condition, influenced by various factors. This study aimed to investigate the potential association between periodontal bone loss and sinus membrane thickness. **Material and Methods:** Cone beam computed tomography (CBCT) images of 249 maxillary sinuses and 327 teeth were examined into this study. Periodontal bone loss was assessed in 4 groups as follows; normal: 0-1.5 mm, mild bone loss: 1.6-3 mm, moderate bone loss: 3.1-4.5 mm, severe bone loss: more than 4.5 mm, while sinus membrane thickness was evaluated in 5 groups as follows; no mucosal thickening, <2 mm (normal), 2 to 4 mm (mild), 4 to 10 mm (moderate), >10 mm (severe). Relationships between periodontal bone loss, age, sex, and sinus mucosa thickness were analyzed. **Results:** The mean (±SD) sinus membrane thickness and periodontal bone loss was 3.09±4.47 mm and 4.73±1.95 mm, respectively. No statistically significant relationship was seen between periodontal bone loss and maxillary sinus mucosal thickness, and between age and sinus membrane thickness. The incidence of severe thickening (>10 mm) was significantly higher in men compared to women. **Conclusion:** Within the limitations of this study, there might be no association between periodontal bone loss and sinus mucosa thickness. Additionally, the presence of periodontal bone loss may not be an indicative of the risk of sinus membrane perforation related to sinus membrane thickness.

**Keywords:** Cone-beam computed tomography; maxillary sinus; alveolar bone loss; periodontitis

**ÖZET Amaç:** Çeşitli faktörlerin etkisi ile 2 mm'yi aşan sinüs zarı kalınlaşması patolojik bir durum olarak kabul edilir. Bu çalışma, periodontal kemik kaybı ile sinüs zarı kalınlığı arasındaki potansiyel ilişkiyi araştırmayı amaçlamaktadır. **Gereç ve Yöntemler:** Bu çalışmada, 249 maksiller sinüs ve 327 dişin konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri incelendi. Periodontal kemik kaybı normal (0-1,5 mm), hafif kemik kaybı (1,6-3 mm), orta düzey kemik kaybı (3,1-4,5 mm), ciddi kemik kaybı (4,5 mm'den fazla) olmak üzere 4 grup olarak değerlendirildi. Sinüs zarı kalınlığı ise 5 grupta değerlendirildi; mukozal kalınlaşma yok, <2 mm (normal), 2-4 mm (hafif), 4-10 mm (orta düzey), >10 mm (ciddi). Periodontal kemik kaybı, yaş, cinsiyet ve sinüs mukozası kalınlığı arasındaki ilişkiler analiz edildi. **Bulgular:** Ortalama (±SS) sinüs zarı kalınlığı ve periodontal kemik kaybı sırasıyla 3,09±4,47 mm ve 4,73±1,95 mm olarak tespit edildi. Periodontal kemik kaybı ile maksiller sinüs mukozal kalınlığı arasında ve yaş ile sinüs zarı kalınlığı arasında istatistiksel olarak anlamlı bir ilişki gözlenmedi. Ciddi kalınlaşma (>10 mm) insidansının, kadınlara göre erkeklerde önemli ölçüde daha yüksek olduğu görüldü. **Sonuç:** Bu çalışmanın sınırlamaları içinde, periodontal kemik kaybı ile sinüs mukozası kalınlığı arasında bir ilişki olabileceği gözlenmemiştir. Ayrıca, periodontal kemik kaybı olmasının, sinüs zarı kalınlığı ile ilişkili sinüs zarı perforasyonu riskinin bir belirtisi olmayabileceği değerlendirilmiştir.

**Anahtar Kelimeler:** Konik ışın bilgisayarlı tomografi; maksiller sinüs; alveolar kemik kaybı; periodontitis

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Periodontitis is a chronic multifactorial inflammatory disease that causes progressive destruction of the periodontium when associated with plaque biofilm. If left untreated, it may result in tooth loss, requiring extraction for teeth severely affected by periodontitis. In such cases, replacing the tooth with an implant is considered. However, severe periodontal destruction leading the tooth loss not only affects alveolar bone height but may also impact the thickness of the maxillary sinus mucosa when planning for implant placement.[1]

The roots of the maxillary first molar and second premolar teeth are in closely situated to the maxillary sinus with potential extension into the sinus cavity. In cases of infection, the sinus membrane may thicken and become more visible on radiographs, presenting as a radio-opaque band at sinus floor.[2] Increased thickness of the maxillary sinus mucosa is a common pathology, influenced by factors, including season, gender, smoking, proximity to endodontic or periodontal lesions, the presence of septae, and gingival phenotype.[3-6] When the sinus membrane thickness exceeds 2 mm, it is considered pathological. Thickness is generally higher in men and increases with age.[1,5-8]

Sinus floor elevation surgery is performed to address bone loss around molars affected by severe periodontitis and raise bone height for implant placement. A common complication is sinus floor membrane perforation, and its relationship with membrane thickness varies in research findings.[2,9-12] Wen et al. suggested the lowest perforation rate when the membrane thickness ranges from 1.5 to 2 mm, while others indicate an association between membrane perforation and thin membrane thickness, suggesting an increased risk in thinner membranes.[2,11]

Periodontal bone loss has also been investigated as a potential cause for sinus mucosa thickening. Some studies suggest an association between neighboring teeth's periodontal lesions and sinus membrane thickness, while others report conflicting results.[1,6,8]

Bacteria, their by-products, and inflammatory cytokines may contribute to sinus mucosal thickening by reaching the sinus through porous maxillary bone or through blood and lymph vessels.[8] Cone beam computed tomography (CBCT) studies by Sheikhi et al. and Phothikhun et al. found significant associations between maxillary sinus mucosal thickening and periodontal bone loss, indicating a potential link in severe cases.[1,8]

CBCT, introduced for craniofacial imaging, and is a precise method for evaluating periodontal defects and paranasal sinuses, offering advantages over traditional CT. CBCT, with its smaller dimensions, cost-effectiveness, shorter exposure time, reduced motion artifacts, and ability to scan small areas, has become a valuable tool in dentistry. Its isotropic voxels allow reliable measurements in any plane, and acquired images can be easily viewed and analyzed using personal computers without additional devices. The higher resolution of CBCT enables detailed examination of small formations in the maxillofacial region, with reduced metal artifacts and the ability to obtain images in coronal, axial, and sagittal planes without superimposition of surrounding anatomical structures.[13-15]

The hypothesis of the study was that periodontal bone loss leads to an increase in sinus membrane thickness. Hence, the purpose of the study is to explore the relationship between periodontal bone loss and maxillary sinus membrane thickness using CBCT images, along with the additional variables of age and gender.

## MATERIAL AND METHODS

This study protocol was approved by the Ethical Committee of Non-Invasive Clinical Research of Kocaeli University (no: GOKAEK-2020/21.01) and was conducted following the Declaration of Helsinki of 1975, as revised in 2000.

This study was planned as a retrospective study evaluating CBCT images from the radiology archive of the Kocaeli University Faculty of Dentistry. The evaluated CBCT images were taken with a Planmeca Promax 3D Max device (Planmeca Oy, Helsinki, Finland) at 96 kVp and 10 mA and were generated using the Planmeca Romexis program (Planmeca Oy).

Inclusion criteria for the study were as follows; absence of any dental treatment in the maxilla, no

presence of decay or periapical lesion, presence of at least one premolar or molar tooth in the maxilla, inclusion of the entire region of interest in the images and having good image quality, and CBCT images belonging to individuals aged 18 years and older.

Exclusion criteria for the study were as follows: CBCT images with any pathological lesion in the maxillary sinus, dental treatment applied to upper molars and premolar teeth, presence of periapical lesion in upper molars and premolar teeth, and developmental anomaly related to tooth root in upper molars and premolar teeth. In cases where fenestration was detected in a tooth, the root with fenestration was excluded from the measurements, and the other roots of the tooth were evaluated for measurement.

## ALVEOLAR BONE LOSS

To assess the alveolar bone loss around the maxillary molar and premolar teeth, axial sections with a thickness of 1 mm were generated by marking the relevant teeth through the center of their pulp chambers on the panoramic image. The cross-sections were traced mesiodistally over the panoramic image with a thickness of 1 mm. In the cross-section with the most significant destruction, measurements were taken buccopalatinally between the cementoenamel junction and the crest of the alveolar bone. The result was recorded for the respective sinus area. After the measurements, they were categorized as follows: "no alveolar bone loss" if there was no bone loss and "alveolar bone loss present" if there was 1.6 mm or more of alveolar bone loss.[16]

According to the classification made by Goodarzi Pour et al. in 2015, alveolar bone loss was evaluated in 4 groups;[16]

1. Normal: 0-1.5 mm
2. Mild bone loss: 1.6-3 mm
3. Moderate bone loss: 3.1-4.5 mm
4. Severe bone loss: more than 4.5 mm

## MAXILLARY SINUS MEMBRANE THICKNESS

The neighboring mucosal thickening to the region with the most significant bone loss was measured in the sagittal section. This measurement was taken perpendicularly from the thickest point of the mucosa to the sinus floor. Sinus mucosa thickness was considered "normal" if it was 2 mm or less and "thickened" if it was more than 2 mm.[17]

Based on the classification made by Rak et al., maxillary sinus membrane thickness was evaluated in 5 groups;[18]

1. No mucosal thickening
2. <2 mm (normal)
3. 2 to 4 mm (mild)
4. 4 to 10 mm (moderate)
5. >10 mm (severe)

## STATISTICAL ANALYSIS

Power analysis was performed using software (G*Power Software version 3.1.9.2, Düsseldorf, Germany) to estimate the minimum required sample size. Type I error and test power was set to 5% and 95% respectively. According to the statistical results based on comparisons in the reference publications, the sample size was calculated as n=316, considering an estimated 20% loss, starting from an initial sample size of 264.

The statistical analysis of the study was performed using MedCalc Statistical Software version 12.7.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2013). Descriptive statistics [mean, standard deviation, minimum, median, maximum, frequency (N), percentage (%)] were used to describe continuous variables. The Fisher exact test was used to examine the relationship between categorical variables. The agreement between two categorical variables was assessed using the Kappa agreement test. In the present study, a significance level of *p*-values less than 0.05 was considered statistically significant.

To evaluate the accuracy of the measurements, a second measurement was performed. This second measurement was conducted by the same researcher who performed the first measurements, and 101 tomographic images were randomly selected from the images used for the initial measurements.

## RESULTS

A total of 1937 CBCT images were examined. Among the 249 patients who met the inclusion criteria, CBCT images of 327 teeth were evaluated for periodontal bone loss, as well as the thickness of the maxillary sinus mucosa adjacent to these teeth. The patients were evaluated into 3 groups according to their age, as 18-35 years old, 35-44 years old, and older than 44 years old. Alveolar bone loss and sinus membrane thickness were calculated by the software (Planmeca Romexis, Planmeca Oy, Helsinki, Finland) on images that met the criteria.

Of the patients, 126 (50.6%) were male, and 123 (49.4%) were female. The mean age of the patients was 40.76±11.54 years. The age range of the participants in the study was between 18 and 66 years. Among the included participants, 32.1% were in the age range of 18-35, 28.1% were in the age range of 35-44, and 39.8% were 44 years and older.

Demographic data of the participants in the study are presented in Table 1.

**TABLE 1:** Demographic variables of the study participants.

| Parameters | n | % | X̄±SD |
|---|---|---|---|
| Gender | | | |
| Male | 126 | 50.6 | |
| Female | 123 | 49.4 | |
| Age | | | |
| 18-35 | 80 | 32.1 | |
| 35-44 | 70 | 28.1 | 40.76±11.54 |
| ≥44 | 99 | 39.8 | |

SD: Standard deviation.

The alveolar bone loss was found to be 4.73±1.95 mm (mean±SD) with a range of 1.2 to 10.9 mm (min to max). The sinus mucosal thickening ranged from 0 to 27.9 mm, with a mean value of 3.09±4.47 mm (mean±SD).

Based on the classification used by Goodarzi Pour et al. for alveolar bone loss, the measurement results revealed that 48.9% of the teeth had severe bone loss, followed by 30% with moderate bone loss, 20.8% with mild bone loss, and 0.3% with normal bone levels (Table 2).[16]

Based on the classification made by Rak et al., maxillary mucosa thickness was found to be as follows: 37% had a normal thickness of less than 2 mm, 23.2% had no thickening, 18% had thickening between 2-4 mm, 14.4% had thickening between 4-10 mm, and 7.3% had thickening of 10 mm and above (Table 2).[18] Based on this classification, 39.7% of the measured maxillary sinuses showed mucosal thickening of 2 mm and above.

When alveolar bone loss was considered to be present if it was 1.6 mm or more, 99.7% of the measured teeth were found to have alveolar bone loss. On the other hand, when mucosal thickening of 2 mm or more was considered as thickening, 35.8% of the measured maxillary sinuses showed mucosal thickening.

There was no statistically significant relationship observed between sinus mucosa thickness and alveolar bone loss. Among teeth with normal limits of bone loss, only one tooth showed mild thickening of 2-4 mm. In the groups with mild, moderate, and severe bone loss, 35.3%, 43.9%, and 33.8%, respec-

**TABLE 2:** The evaluation of alveolar bone loss data according to the classification made by Goodarzi Pour et al. and the evaluation of maxillary mucosa thickness data based on the classification by Rak et al.[16,18]

| | Periodontal bone loss | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Normal | | Mild bone loss | | Moderate bone loss | | Severe bone loss | | |
| Sinus membrane thickness | n | % | n | % | n | % | n | % | P* |
| No mucosal thickening | 0 | 0 | 21 | 30.9 | 24 | 24.5 | 31 | 19.4 | 0.266 |
| Normal (<2 mm) | 0 | 0 | 24 | 35.3 | 43 | 43.9 | 54 | 33.8 | 0.336 |
| Mild (2-4 mm) | 1 | 100 | 12 | 17.6 | 14 | 14.3 | 32 | 20 | 0.117 |
| Moderate (4-10) | 0 | 0 | 9 | 13.2 | 10 | 10.2 | 27 | 17.5 | 0.408 |
| Severe (>10 mm) | 0 | 0 | 2 | 2.9 | 7 | 7.1 | 15 | 9.4 | 0.393 |

*p<0.05.

tively, showed thickening of less than 2 mm, which is considered normal. There was no statistically significant relationship observed between sinus mucosa thickness and alveolar bone loss. Among teeth with alveolar bone loss (1.6 mm and above), 64.1% showed normal sinus mucosa thickness (2 mm and below). In one tooth, no alveolar bone loss was observed, and the sinus mucosa in the adjacent jaw was also found to be normal.

There was a statistically significant relationship between sinus mucosa thickness and gender ($p<0.05$). The incidence of severe thickening (>10 mm) was higher in males compared to females. Among 167 sinuses from male patients, 58 showed mucosal thickness of less than 2 mm, accounting for 34.7% of all maxillary sinuses in males.

Similarly, when sinus mucosa thickness was evaluated 63 out of 160 sinuses from female patients had mucosal thickness of less than 2 mm, representing 39.4% of all maxillary sinuses in females. In both males and females, the most common finding was mucosal thickness of less than 2 mm, which was considered normal (Table 3).

There was no statistically significant relationship between age and sinus mucosa thickness ($p>0.05$) (Table 4). Among the participants in the age group of 18-35 years, the mean thickness of the maxillary sinus mucosa was 3.32±5.28 mm (mean±SD), with a range of 0-27.9 mm. In the age group of 35-44 years, the mean thickness was 2.92±4.2 mm (mean±SD), ranging from 0 to 22.2 mm. For individuals aged 44 years and above, the mean thickness was 3.04±3.9 mm (mean±SD), with a range of 0-18 mm.

**TABLE 3:** The distribution of sinus mucosa thickness according to gender.

| | Male | | Female | | |
|---|---|---|---|---|---|
| **Sinus membrane thickness** | **n** | **%** | **n** | **%** | **p*** |
| No mucosal thickening | 35 | 21 | 41 | 25.6 | 0.386 |
| Normal (<2 mm) | 58 | 34.7 | 63 | 39.4 | 0.450 |
| Mild (2-4 mm) | 33 | 19.8 | 26 | 16.3 | 0.496 |
| Moderate (4-10) | 23 | 13.8 | 24 | 15 | 0.874 |
| Severe (>10 mm) | 18 | 10.8 | 6 | 3.8 | 0.026 |

*p<0.05.

**TABLE 4:** Distribution of sinus membrane thickness according to age.

| | | Sinus membrane thickness (mm) $\bar{X}$±SD | |
|---|---|---|---|
| | **n** | **Median (Minimum-Maksimum)** | **p*** |
| Age | | | |
| 18-35 | 107 | 3.32±5.28 | |
| | | 1.6 (0-27.9) | |
| 35-44 | 91 | 2.92±4.2 | 0.892 |
| | | 1.6 (0-22.2) | |
| ≥44 | 129 | 3.04±3.9 | |
| | | 1.6 (0-18) | |

*p<0.05; SD: Standard deviation.

## DISCUSSION

The aim of this study was to assess the relationship between periodontal bone loss and thickening of the maxillary sinus mucosa. CBCT images were retrospectively examined. The CBCT images of 249 patients, ranging in age from 18 to 66, were included, and the thickness of the maxillary sinus mucosa in proximity to 327 teeth was evaluated. The mean age of the participants in our study was 40.76±11.54 years, and periodontal bone loss was classified into four categories following the classification by Goodarzi Pour et al., while sinus mucosa thickness was divided into five groups based on the classification by Rak et al.[16,18]

Various radiographic techniques are assessing the maxillary sinus, with CBCT considered more reliable than traditional methods.[19,20] CBCT offers clear, undistorted results when evaluating the desired area. When evaluating maxillary sinus mucosal thickening, traditional radiographic methods are considered less reliable in the literature.[5,21] Limited studies have used CBCT to assess sinus mucosal thickness.[6,17,22]

Extended edentulism in the maxillary posterior contributes to alveolar bone atrophy, intensified by advanced periodontal destruction and maxillary sinus pneumatization, posing challenges for dental implant procedures, Maxillary sinus augmentation is routinely performed to address bone loss and enable successful implant placement, especially in cases with increased maxillary sinus pneumatization.[23] How-

ever, mucosal thickness is a significant factor, influencing the risk of mucosal perforation, a common complication in sinus augmentation surgery.[6,9,17] Thick gingival phenotype, periodontal diseases, smoking, and seasonal allergies can all influence the thickness of the maxillary sinus mucosa.[6,24]

Sinus pathologies are common, with studies indicating a high prevalence in patients planned for maxillary sinus augmentation.[25-27] In our study, sinus mucosal thickening was observed in 35.8% of the measured maxillary sinuses.

Severe mucosal thickening poses challenges during sinus augmentation, increasing the risk of procedure failure or complications.[22,28] The literature suggests that when sinus mucosa thickness exceeds 10 mm, there is a risk of ostium blockage and subsequent sinusitis during elevation and grafting.[28-31] Studies show a significant correlation between mucosal thickness and perforation rate, with the lowest rate observed at 1.5-2 mm.[22]

In the literature, some studies consider maxillary sinus mucosal thickness as thickened when it is 1 mm, 2 mm, and over 3 mm.1,[3,6-8,24] In our study, mucosal thickness greater than 2 mm was considered as "thickened". The average mucosal thickness of the evaluated sinuses in our study was found to be 3.09±4.47 mm. Other studies that have reported mucosal thickness include Lin et al. with an average of 1.32±0.87 mm, Wen et al. with an average of 1.78±1.99 mm, and Lum et al. with an average of 2.14±3.51 mm.[2,12,22]

Regarding the relationship between periodontal bone loss and mucosal thickness in studies, Phothikhun et al. reported sinus mucosal thickness as 5.0±3.9 mm, Zhang et al. as 4.2±2.1 mm, and Sheikhi et al. as 4.68±5.25 mm.[1,7,8] Studies investigating the relationship between periodontal bone loss and mucosal thickness showed varying results, emphasizing the need for standardized criteria in future research. Phothikhun et al. evaluated 250 CBCT images and considered mucosal thickness of 1 mm and above as thickened.[8] They reported a higher prevalence of mucosal thickening (>49 years of age) in the older age group and found a significant association between mucosal thickening and severe periodontal bone loss.

In their study, Zhang et al. investigated the relationship between the periodontal condition of maxillary molar teeth and sinus mucosal thickening using CBCT, revealing a significant correlation between periodontal bone loss and mucosal thickness.[7] They also noted higher mucosal thickness in the older age group. In contrast, our study did not find a statistically significant relationship between age and sinus mucosal thickness.

Sheikhi et al. evaluated 180 CBCT images of patients aged between 13 and 81, establishing a relationship between periodontal bone loss and maxillary sinus mucosal thickness.[1] They reported an increase in periodontal bone loss and sinus mucosal thickness with age. However, Shanbhag et al., in their study with 243 patients aged between 15 and 90 and 485 CBCT images, found no correlation between periodontal bone loss and maxillary sinus mucosal thickness, aligning with our study's findings.[32]

Regarding the relationship between periodontal health and sinus mucosal thickness, the results are conflicting. In the present study, there was no significant relationship between periodontal bone loss and sinus mucosal thickness.

When examining the relationship between maxillary sinus mucosal thickness and gender in the literature, studies show conflicting results. Some studies suggest that sinus mucosal thickening is more common in males while others report a higher prevalence in females.[1,6-8,24,33] In the present study, a higher incidence of sinus mucosal thickening greater than 10 mm was observed in males. In the study conducted by Vallo et al., the frequency of sinus mucosal thickening was reported as 18% for male patients and 8% for female patients, while Ren et al. reported frequencies of 58.3% for males and 42.5% for females.[5,34] There are inconsistencies among studies regarding the frequency of sinus mucosal thickening in the literature. Discrepancies in the literature's findings may be due to variations in inclusion criteria among the studies.[7] The reason for thicker maxillary mucosa in males could potentially be linked to a higher rate of smoking among men in the population, although the smoking status of the patients in our study was not known.

Among the limitations of this study is its reliance solely on CBCT evaluation. Information regarding systemic diseases, smoking habits, and other factors for the individuals assessed in this study is not available.

## CONCLUSION

The study results indicate that there is no notable correlation between periodontal bone loss or age and sinus membrane thickness. However, a noteworthy observation is a higher prevalence of sinus membrane thickness surpassing 10 mm among male participants.


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### *Conflict of Interest*

*No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.*

### *Authorship Contributions*

***Idea/Concept:*** *Esra Güzeldemir Akçakanat, Huriye Çakır;* ***Design:*** *Esra Güzeldemir Akçakanat, Huriye Çakır;* ***Control/Supervision:*** *Esra Güzeldemir Akçakanat, Huriye Çakır, Vecihe Merve Balta Uysal, Enver Alper Sinanoğlu;* ***Data Collection and/or Processing:*** *Huriye Çakır;* ***Analysis and/or Interpretation:*** *Esra Güzeldemir Akçakanat, Huriye Çakır, Vecihe Merve Balta Uysal, Enver Alper Sinanoğlu;* ***Literature Review:*** *Huriye Çakır, Vecihe Merve Balta Uysal;* ***Writing the Article:*** *Esra Güzeldemir Akçakanat, Vecihe Merve Balta Uysal, Yener Oğuz;* ***Critical Review:*** *Esra Güzeldemir Akçakanat, Yener Oğuz;* ***References and Fundings:*** *Esra Güzeldemir Akçakanat.*



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