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Relationship of Periapical and Periodontal Pathologies of Maxillary First Molars with Maxillary Sinus Membrane Thickness: A Retrospective CBCT Analysis

Maksiller Birinci Molarların Periapikal ve Periodontal Patolojilerinin Maksiller Sinüs Membran Kalınlığı ile İlişkisi: Retrospektif Bir KIBT Analizi

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ABSTRACT

Background: This study aimed to assess the association between periapical lesions (PLs), periodontal bone loss (PBL), and maxillary sinus mucosal thickness (SMT) in the maxillary first molar (M1) region using cone-beam computed tomography (CBCT).

Materials and Methods: In this retrospective cross-sectional study, 240 maxillary sinuses adjacent to the M1 were examined using CBCT images from 140 patients (mean age: 32.62 ± 12.22 years). SMT values were measured perpendicular to the sinus floor, with values exceeding 2 mm defined as pathological. PL size, PL-sinus distance, and PBL severity were categorized according to CBCT-based criteria. Statistical analysis was performed using non-parametric tests, and intra-observer reliability was evaluated using the intraclass correlation coefficient (ICC).

Results: Statistical analysis revealed excellent measurement reliability (ICC: 0.96). While gender had no significant impact on SMT ($p > 0.05$), increased SMT was clearly correlated with odontogenic pathologies, specifically PL and advanced PBL associated with the M1. This association was observed to intensify when lesions were closer to the sinus floor or directly affected its integrity.

Conclusion: CBCT findings demonstrate an association between periapical and periodontal pathologies in the M1 region and maxillary sinus mucosal thickening, supporting odontogenic effects on the Schneiderian membrane. A detailed CBCT evaluation of the relationship between dental pathologies and the maxillary sinus may enhance the accuracy of radiological diagnosis and contribute to improved clinical decision-making and appropriate referral planning.

Keywords: Cone-beam computed tomography, maxillary sinus, sinus mucosal thickness

ÖZ

Amaç: Bu çalışmanın amacı; maksiller birinci molarlara (M1) komşu periapikal lezyonlar (PL) ve periodontal kemik kaybı (PK) ile maksiller sinüs mukoza kalınlığı (SMK) arasındaki ilişkinin konik ışınlı bilgisayarlı tomografi (KIBT) aracılığıyla değerlendirilmesidir.

Gereç ve Yöntemler: Bu retrospektif kesitsel çalışma kapsamında 140 hastanın (yaş ortalaması: 32,62 ± 12,22) KIBT görüntüleri üzerinden M1 komşuluğundaki 240 maksiller sinüs incelendi. Sinüs tabanına dik ölçülen SMK değerlerinde 2 mm eşik kabul edilerek üzerindeki ölçümler patolojik olarak tanımlanmıştır. PL boyutu, PL-sinüs mesafesi ve PK şiddeti KIBT kriterlerine göre sınıflandırılırken, verilerin analizinde parametrik olmayan testler ve gözlemci içi güvenilirlik için ICC analizi kullanıldı.

Bulgular: Ölçüm güvenilirliği mükemmel düzeydeydi (ICC: 0,96). Cinsiyetin SMK üzerinde anlamlı bir etkisi saptanmazken ($p > 0,05$), artmış SMK'nın M1 kaynaklı PL'lar ve ileri derece PK ile korelasyon gösterdiği belirlenmiştir. Özellikle sinüs tabanı ile doğrudan temas kuran veya tabanı etkileyen lezyonlarda bu patolojik ilişkinin şiddetlendiği saptandı.

Sonuç: Bu KIBT bulguları, M1 bölgesindeki periapikal ve periodontal patolojiler ile maksiller sinüs mukozal kalınlığı arasındaki ilişkiyi açıkça ortaya koymakta ve Schneiderian membranı üzerindeki odontojenik etkileri desteklemektedir. Dental patolojiler ile maksiller sinüs arasındaki ilişkinin KIBT ile ayrıntılı değerlendirilmesi, radyolojik tanının doğruluğunu artırarak klinik karar verme sürecine ve uygun sevk planlamasına katkı sağlayabilir.

Anahtar Kelimeler: Konik ışınlı bilgisayarlı tomografi, maksiller sinüs, sinüs mukozal kalınlığı

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Introduction

Because of the well-known anatomical proximity between the root apices of maxillary posterior teeth and the maxillary sinus floor, odontogenic infections originating from these teeth may directly affect the Schneiderian membrane and contribute to inflammatory changes within the sinus cavity, potentially leading to odontogenic maxillary sinusitis (1,2). This anatomical relationship is of particular clinical importance in the maxillary first molar (M1) region, where the distance between the root apices and the sinus floor is often minimal (1,2). Several odontogenic factors, most notably periapical lesions (PLs) and advanced periodontal bone loss (PBL), have been associated with maxillary sinus mucosal thickening, while deep carious lesions and inadequate endodontic treatment may further contribute to this process (1-3). Chronic inflammatory conditions of odontogenic origin are thought to induce reactive changes in the Schneiderian membrane, which may range from mild mucosal thickening to clinically relevant sinus pathology (3-5).

Conventional two-dimensional imaging techniques, including periapical and panoramic radiographs, are limited by anatomical superimposition, magnification, and geometric distortion, which may obscure the true extent of periapical pathology and hinder accurate assessment of the spatial relationship between odontogenic lesions and the maxillary sinus (2,6). Cone-beam computed tomography (CBCT), however, allows three-dimensional and multiplanar visualization of dental structures, alveolar bone, and the maxillary sinus with high spatial resolution, making it particularly suitable for evaluating odontogenic sinus involvement and lesion-sinus relationships (7-9). For this reason, CBCT has increasingly been adopted as the imaging modality of choice in the assessment of odontogenic maxillary sinus pathology (4,10).

Several CBCT-based investigations have demonstrated an association between apical periodontitis and increased maxillary sinus mucosal thickness (SMT), reporting a significantly higher prevalence of mucosal thickening in teeth affected by PL compared with healthy teeth (1,2,8). In addition, periodontal disease involving maxillary posterior teeth has been shown to influence sinus mucosal health, supporting the concept that both endodontic and periodontal inflammatory processes may affect the maxillary sinus (3,11). Nevertheless, comparisons between studies remain challenging because lesion size thresholds, definitions of mucosal thickening, and criteria used to describe lesion-sinus relationships are not uniform across the literature (7). While many studies have primarily focused on the presence or absence of periapical pathology, fewer investigations have evaluated PL size, lesion–sinus spatial relationship, severity of PBL, and SMT simultaneously using standardized classification systems within a single analytical model (8). This limitation is particularly relevant for M1, whose anatomical characteristics predispose them to odontogenic sinus involvement and whose pathological conditions may therefore have a greater impact on sinus health (1,2).

Recent studies suggest that larger PL, particularly those in direct contact with or extending into the maxillary sinus floor, are associated with more marked mucosal thickening and an increased risk of odontogenic maxillary sinusitis (12). Findings from meta-analyses and contemporary CBCT-based studies further highlight the significant role of odontogenic factors in the development of maxillary sinus pathology and emphasize the importance of thorough radiological evaluation in affected individuals (6,13).

Although numerous studies have investigated the relationship between periapical pathologies and maxillary sinus mucosal thickening, a substantial proportion of these studies did not simultaneously evaluate PL size, the distance between the lesion and the sinus floor, PBL, and SMT using detailed, standardized classification systems. Accordingly, this study aims to clarify the role of odontogenic factors in sinus pathology and to support more-informed clinical decision-making in dental and maxillofacial practice by analyzing PL characteristics, PBL severity, and SMT.

Materials and Methods

Study Design and Sample Selection

The patient sample was obtained from the archives of the Department of Oral and Dentomaxillofacial Radiology, Faculty of Dentistry, Erzincan Binali Yıldırım University. CBCT images of patients acquired between January 2025 and October 2025 were included. These scans had originally been taken for routine clinical purposes, including evaluation of impacted teeth, orthodontic treatment planning, and implant assessment. The study included CBCT scans of individuals aged 18 years and older who had a clearly visible maxillary sinus floor and Schneiderian membrane adjacent to at least one M1. We excluded scans indicating a history of regional surgery (such as maxillary sinus surgery or root resections), trauma, or incomplete root development. Additionally, cases involving fixed prosthetics, extensive artifacts, or poor diagnostic quality were excluded from the analysis.

Acquisition of CBCT Images

All CBCT images were acquired using the PlanMeca ProMax® 3D Classic CBCT, with 0.2 mm section thickness, operating parameters of 90 kVp and 6.3 mA, an 8 x 8 cm

field of view, a 12.1-second acquisition time, and a voxel size of 200 μm. Image analysis was performed with Romexis 6.2.1 (R® software, Planmeca, Helsinki, Finland) on a 24-inch Dell LCD screen (Dell, TX, USA) with a resolution of 1920 × 1080 pixels.

Assessment of CBCT Images

This retrospective study analyzed CBCT scans to evaluate the relationship between the M1 and the adjacent Schneiderian membrane. The study focused exclusively on the M1 region due to its anatomical significance and high frequency of sinus floor involvement (12). Thickening of the maxillary sinus mucosa was measured along the long axis of M1, perpendicular to the maxillary sinus floor, using the measuring tool in Romexis software. The presence of mucosal thickening on the floor of the maxillary sinus was evaluated on coronal and sagittal CBCT images. The membrane was classified as "thickened" if its thickness exceeded 2 mm. In accordance with the comprehensive review by Psillas et al. (6) and the CBCT-based analysis by Capelli and Gatti(14), maxillary SMT greater than 2 mm was considered indicative of pathologic SMT. This measurement was taken from the sinus floor immediately superior to the M1 root apices, extending to the highest point of the mucosa. PL-sinus floor relationships were classified as follows: lesions distant from the sinus floor, lesions in contact with the sinus floor, and lesions penetrating the sinus floor (Figure 1).

For each category, the prevalence of sinus mucosal thickening ⩾2 mm was calculated and expressed as frequencies and percentages. PL size was assessed on CBCT images by measuring the maximum linear diameter of each lesion on the section in which it appeared largest. Lesion size thresholds were based on the CBCT-periapical index (CBCT-PAI) system described by Estrela et al. (15) and defined according to the maximum linear diameter of the lesion measured in millimeters on CBCT images. For exploratory analyses, CBCT-PAI scores were collapsed into three categories: small (⩽2 mm), medium (>2-⩽4 mm), and large (>4 mm) (15). PBL was evaluated on sagittal images by measuring the mesial and distal alveolar bone levels of maxillary first molars and expressing the loss as a percentage of the normal periodontal bone height. Normal periodontal bone height was defined as the distance from the physiologic bone level, located 2 mm apical to the cemento-enamel junction, to the root apex. PBL was classified as severe when >50% bone loss was present at any tooth surface, moderate when 25%-50% bone loss was observed, and normal to mild when bone loss was <25% (16). All SMT measurements were performed by a single observer (M.A.), an oral and maxillofacial radiologist with 3 years of clinical experience. To assess intra-observer reliability, all measurements were repeated by the same observer at two time points, with a minimum interval of two weeks between sessions.

Ethical Approval

This retrospective, cross-sectional study was conducted in compliance with the ethical standards of the Declaration of Helsinki (1964, and subsequent revisions) and was approved by the Non-Invasive Clinical Research Ethics Committee of Erzincan Binali Yıldırım University (decision number: 2025-18/04, date: 25.12.2025). Informed consent was waived by the Ethics Committee due to the retrospective design of the study.

Statistical Analysis

Descriptive statistics were presented as mean ± standard deviation, median, and minimum–maximum values for continuous variables, and as frequencies and percentages for categorical variables. Continuous variables were tested for normality using the Shapiro-Wilk test and were found to be non-normally distributed; non-parametric tests were applied. Comparisons of SMT between two independent groups were performed using the Mann-Whitney U test, while comparisons among more than two groups were

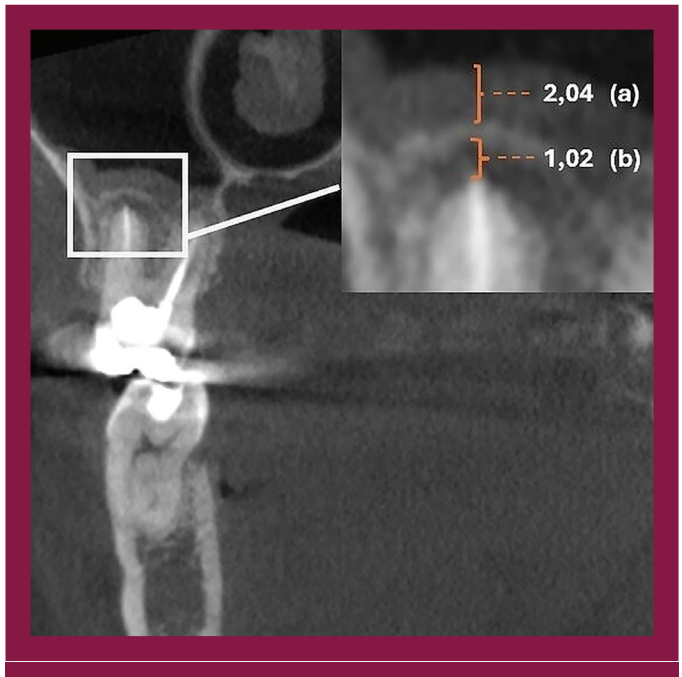

Figure 1. Representative CBCT images demonstrating sinus mucosal thickening associated with odontogenic factors. (a) Coronal CBCT section showing increased maxillary SMT adjacent to a maxillary first molar with periapical pathology, (b) sagittal CBCT image illustrating localized sinus mucosal thickening related to a root canal–treated maxillary first molar. CBCT, cone-beam computed tomography; SMT, sinus mucosal thickness.

conducted using the Kruskal-Wallis test with Bonferroni correction for post-hoc analyses. Associations between categorical variables were assessed using the chi-square test. Correlations between age and SMT were evaluated using Spearman's rank correlation coefficient. The agreement between repeated measurements was evaluated using the intraclass correlation coefficient (ICC). All analyses were performed in IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) with a significance level of $p < 0.05$. Although no a priori sample size calculation was performed given the retrospective design, a post-hoc power analysis confirmed that the study achieved adequate statistical power (>80%) for the primary comparisons (α: 0.05).

Results

A total of 140 patients met the inclusion criteria, (70 females, 70 males) with a mean age of 32.62 ± 12.22 years (females: 32.16 ± 11.73; males: 33.09 ± 12.77). Because maxillary molars were present unilaterally in some patients, a total of 240 maxillary sinuses were evaluated. Intra-class correlation coefficient analysis demonstrated excellent agreement between repeated measurements, with an ICC of 0.96, indicating high measurement reproducibility. There was no statistically significant difference in SMT between genders (male: 1.48 ± 2.00 mm; female: 1.65 ± 2.47 mm; $p = 0.742$). Clinical status of the 240 evaluated M1s, 145 (60.4%) were clinically normal, 48 (20.0%) were endodontically treated, and 47 (19.6%) were carious. The prevalence of PL was 23.8% (n = 57), and that of PBL was 19.2% (n = 46). A progressive increase in SMT was observed with increasing PL size. Teeth without PLs had minimal mucosal thickness, whereas teeth with small, medium, and large PLs had progressively higher median mucosal thickness. Differences among lesion size categories were statistically significant (Kruskal-Wallis test, $p < 0.001$; Table 1). The proximity of PLs to the sinus floor significantly increased the prevalence of SMT ≥2 mm (chi-square test, $p < 0.001$) (Table 2).

While the prevalence was 18.6% in sinuses without lesions, it increased markedly to 79.5-83.3% in sinuses with lesions, regardless of their specific relationship (distant, contacting, or penetrating) to the sinus floor. When PBL severity was analyzed, SMT differed significantly among the three categories (<25%, 25-50%, and >50% bone loss) (Kruskal-Wallis, $p = 0.008$) (Figure 2).

Sinuses associated with severe PBL (>50%) showed the greatest mucosal thickness (median: 3.86 mm), whereas those with mild bone loss (<25%) showed relatively limited mucosal changes. Furthermore, the prevalence of SMT >2 mm increased progressively with PBL severity (33.3%, 58.8%, and 86.7%, respectively), and this trend was statistically significant (chi-square test, $p < 0.001$).

Discussion

The present study utilized CBCT imaging to investigate the influence of periodontal and periapical conditions of M1 on SMT. The measurements demonstrated excellent reproducibility with an ICC of 0.96, underscoring the high reliability of the radiographic assessments. In our study, no statistically significant effect of gender on SMT was found ($p = 0.742$). These findings are consistent with Janner et al. (17), who suggested that gender is not a determining factor for mucosal thickness. However, this contrasts with other studies, such as those by Phothikhun et al. (16) and Shanbhag et al. (1), which reported a higher prevalence of mucosal thickening in males. A notable outcome of this investigation is the substantial influence of PL on SMT. We observed a significant contrast in pathological mucosal thickening (>2 mm): 18.6% in teeth without lesions versus more than 80% in those with lesions ($p < 0.001$). These observations corroborate the findings of Lu et al. (2) and Shanbhag et

Table 1. Comparison of maxillary sinus mucosal thickness according to periapical lesion size.

Periapical lesion size	Teeth (n)	Median mucosal thickness (IQR), mm	p value
No periapical lesion	183	0.00 (0.00-1.46)	0.000..*
Small lesion	24	2.41 (1.88-3.12)	
Medium lesion	21	2.95 (2.26-3.81)	
Large lesion	12	3.88 (2.94-6.21)	

*Kruskal-Wallis test, $p < 0.001$. IQR, interquartile range.

Table 2. Prevalence of maxillary sinus mucosal thickening (≥2 mm)according to the proximity of periapical lesions to the sinus floor.

Lesion–sinus floor relationship	Teeth (n)	Mucosal thickness ≥2 mm, n (%)	p value
No periapical lesion	183	34 (18.6)	0.000..*
Lesion distant from sinus floor	12	10 (83.3)	
Lesion contacting sinus floor	39	31 (79.5)	
Lesion penetrating sinus floor	6	5 (83.3)	

*Chi-square test, $p < 0.001$.

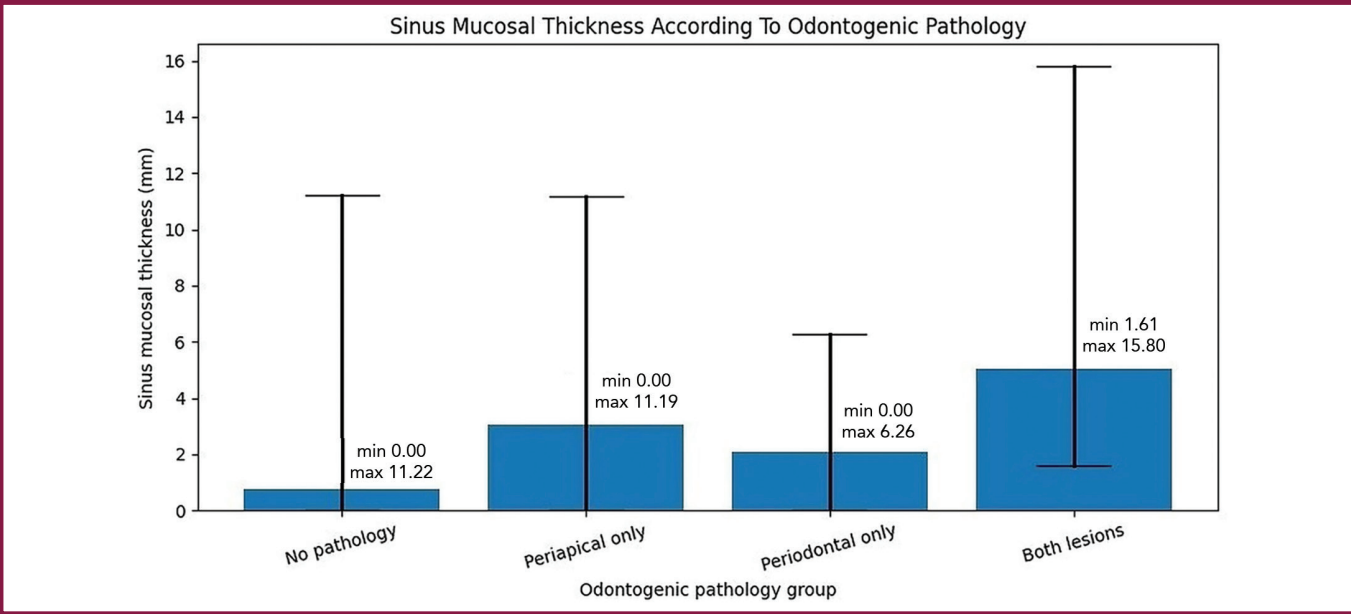

Figure 2. Sinus mucosal thickness according to odontogenic pathology. Bar chart illustrating mean sinus mucosal thickness according to odontogenic pathology. Bar heights represent mean values, while vertical whiskers with terminal caps indicate the minimum and maximum measurements for each group. (Kruskal-Wallis test, $p < 0.001$).

al. (1). Lu et al. (2), for instance, demonstrated that the prevalence of mucosal thickening rises from 41.5% to 100% in correlation with the severity of apical periodontitis. Furthermore, studies by Simuntis et al. (8) identify periapical pathology as a leading factor causing reactive hyperplasia of the sinus mucosa. Gomes et al. (18) reported that teeth exhibiting combined periodontal and periapical pathology were associated with the greatest SMT values, supporting the concept of a cumulative inflammatory burden. This observation aligns closely with our findings, in which the highest SMT values were recorded in M1 with severe PBL. We also observed a progressive increase in SMT with increasing PL ($p < 0.001$). This supports the findings of Oliveira et al. (4) and Goller-Bulut et al. (19) regarding the positive correlation between lesion volume and mucosal thickness. Our evaluation of lesion proximity revealed a significant link between lesion presence and mucosal thickening ⩾2 mm. Regardless of whether the lesions were distant from, in contact with, or penetrating the sinus floor, all groups demonstrated markedly higher rates of thickening than the control group. This finding suggests that the mere existence of periapical pathology is the dominant factor affecting the sinus mucosa, rather than its exact spatial relationship.

Phothikhun et al. (16) demonstrated a significant association between severe PBL and SMT, reporting that sinuses adjacent to teeth with advanced periodontal destruction were approximately three times more likely to exhibit mucosal thickening. Similarly, Zhang et al. (10) used CBCT to assess the periodontal condition of M1 and revealed a significant correlation between PBL and SMT; they also noted greater thickness in older age groups. Supporting this, Sheikhi et al. (11) evaluated 180 CBCT images (patients aged 13-81) and established a similar relationship, reporting that both PBL and SMT increase with age. In contrast, Çakır et al. (20) did not find a statistically significant relationship between age and SMT. Similarly, Shanbhag et al. (1), in a study involving 243 patients (485 CBCT images, aged 15-90), found no correlation between PBL and SMT, which aligns with the lack of significant associations reported by Çakır et al. (20). A statistically significant positive correlation was observed between the severity of PBL and SMT ($p < 0.001$). Our results demonstrated a progressive increase in SMT values corresponding to the extent of bone destruction. Specifically, teeth with severe bone loss (>50%) were associated with the highest mean mucosal thickness (6.11 mm) and the highest prevalence of pathological thickening (86.7%), whereas teeth with mild bone loss (<25%) showed relatively limited mucosal changes (mean: 2.02 mm). Furthermore, we observed a significant positive correlation between age and SMT (Spearman's rho: 0.33, $p < 0.001$). This indicates that mucosal thickness increases with advancing age, a finding that is compatible with the results reported by Zhang et al. (10) and Sheikhi et al. (11).

Study Limitations

This study has limitations. First, it was retrospective and performed at a single center, and only maxillary first molars were evaluated; therefore, the findings may not fully apply to other posterior teeth or to different patient groups. Second, we did not have clinical information, such as sinonasal symptoms, endoscopic findings, or microbiological results; therefore, mucosal thickening on CBCT cannot be directly interpreted as clinical sinusitis. Third, some subgroups were small (e.g., those with severe bone loss or lesions penetrating the sinus floor), which may have reduced statistical power. In addition, no a priori sample size calculation was performed. Although all eligible images were included and the post-hoc analysis demonstrated adequate statistical power (>80%), a prospectively calculated sample size would have strengthened the methodological rigor. Furthermore, statistical analyses were limited to univariate comparisons, restricting the ability to identify independent predictors of SMT in the presence of potential confounders. Finally, some patients' bilateral sinus measurements were analyzed without adjusting for within-patient correlation, which may have introduced partial non-independence into the dataset.

Conclusion

This CBCT-based study demonstrates that dental pathology adjacent to the maxillary first molar is associated with increased maxillary SMT. Both PLs and PBL were independently related to greater mucosal thickening; larger PLs and more severe bone loss were associated with proportionally greater mucosal changes. Lesions in closer proximity to the sinus floor were also associated with higher rates of SMT ⩾2 mm. Overall, careful CBCT evaluation of teeth and supporting tissues adjacent to the sinus may help avoid missed odontogenic causes and support more appropriate management.

Ethics

Ethics Committee Approval: This retrospective, cross-sectional study was conducted in compliance with the ethical standards of the Declaration of Helsinki (1964, and subsequent revisions) and was approved by the Non-Invasive Clinical Research Ethics Committee of Erzincan Binali Yıldırım University (decision number: 2025-18/04, date: 25.12.2025).

Informed Consent: Informed consent was waived by the Ethics Committee due to the retrospective design of the study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.O., Concept: A.O., Design: A.O., Data Collection or Processing: M.A., Analysis or Interpretation: M.A., Literature Search: M.A., Writing: A.O.

Conflict of Interest: No conflict of interest was declared by the authors.

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