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Evaluation of maxillary sinus variations using cone beam computed tomography and their association with posterior dental pathologies

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Abstract:
Maxillary sinus anatomical variations and mucosal abnormalities are frequently encountered on dental cone-beam computed tomography, but their relationship with posterior dental pathologies requires careful radiographic assessment. This retrospective CBCT study evaluated 300 patients and 600 maxillary sinuses for septa, pneumatization, mucosal thickening, retention cysts, ostium obstruction, periapical lesions, periodontal bone loss, endodontic status and root proximity to the sinus floor. Mucosal thickening was observed in 196 sinuses (32.7%), sinus septa in 135 (22.5%), marked alveolar pneumatization in 118 (19.7%) and retention cyst/polyp-like opacity in 52 (8.7%). Periapical lesions (adjusted OR=3.12, 95% CI=2.01-4.86, p<0.001), severe periodontal bone loss (adjusted OR=2.28, p=0.003) and direct root contact with the sinus floor (adjusted OR=2.06, p=0.011) were significantly associated with mucosal thickening. Thus, CBCT provides clinically relevant information on sinus anatomy and odontogenic risk indicators, supporting its careful interpretation before posterior maxillary dental procedures.

Keywords: Maxillary sinus, cone-beam computed tomography (CBCT), mucosal thickening, periapical lesion, odontogenic sinusitis, posterior maxilla

Background:
The maxillary sinus is closely related to posterior maxillary teeth, alveolar bone and the nasal cavity. Its anatomy varies considerably among individuals and may be altered by age, tooth loss, pneumatization, inflammation, trauma and previous dental procedures **[1, 2]**. Dental cone-beam computed tomography is widely used for implant planning, endodontic diagnosis, impacted teeth and maxillofacial evaluation. Because CBCT includes the maxillary sinus in many posterior maxillary scans, anatomical variations and mucosal abnormalities are frequently detected incidentally **[3-5]**. Sinus septa, recesses, alveolar pneumatization and proximity of tooth roots to the sinus floor are clinically important. They may increase the complexity of sinus lift surgery, implant placement, extraction, endodontic treatment and management of oroantral communication **[6-8]**. Mucosal thickening is the most common sinus abnormality on CBCT. Although it may be related to allergy, viral infection, or rhinogenic sinusitis, odontogenic inflammation from periapical lesions, periodontal disease and endodontic complications can also contribute to sinus mucosal changes **[9-12]**. The posterior maxillary first molar and second molar roots are commonly near the sinus floor. When periapical inflammation occurs in these teeth, the thin intervening bone can permit inflammatory spread to the Schneiderian membrane, resulting in localized mucosal thickening **[13-16]**. CBCT is superior to two-dimensional imaging for evaluating root-sinus relationships, apical lesions, bony dehiscence and sinus floor morphology. It reduces superimposition and allows multiplanar assessment, which is useful when odontogenic sinus involvement is suspected **[17-20]**. Despite these advantages, the clinical interpretation of sinus findings requires caution. Mild mucosal thickening may be incidental and asymptomatic. The radiographic diagnosis of odontogenic sinusitis should consider distribution, dental focus, unilateral predominance, ostiomeatal complex status and clinical symptoms **[21-24]**. Existing studies show variable prevalence of sinus anatomical variations and pathology because definitions, thresholds for mucosal thickening, scan indications, age distribution and dental status differs. More region-specific data are useful for dental treatment planning. The present study aimed to evaluate maxillary sinus anatomical variations using cone-beam computed tomography and to assess their association with posterior dental pathologies **[25-30]**. Therefore, it is of interest to evaluate the maxillary sinus anatomical variations on CBCT and assess their association with posterior dental pathologies and root proximity to the sinus floor.

Materials and Methods:
This retrospective observational study was performed using archived CBCT scans taken for dental diagnostic purposes.

Three hundred patients aged 18-75 years were included, yielding 600 maxillary sinuses for evaluation. Scans were selected from a radiology database over 18 months. Inclusion criteria were CBCT scans showing both maxillary sinuses and posterior maxillary teeth from first premolar to second molar region with adequate diagnostic quality. Exclusion criteria were previous maxillary sinus surgery, maxillofacial trauma, cystic or neoplastic lesions involving the sinus, cleft-related deformity, craniofacial syndromes, poor image quality and incomplete visualization of sinus boundaries. CBCT datasets were evaluated in axial, coronal and sagittal planes by two calibrated oral radiologists. Sinus anatomical variations recorded included septa, alveolar pneumatization, hypoplasia and accessory ostium when visible. Sinus abnormalities recorded included mucosal thickening greater than 2 mm, retention cyst/polyp-like opacity, partial opacification and ostium obstruction. Posterior dental variables included presence of periapical lesion, endodontic treatment, severe periodontal bone loss, furcation involvement, vertical root fracture suspicion and relationship of root apex to sinus floor. Root-sinus relationship was categorized as separated by bone, in contact with sinus floor, or protruding into sinus cavity. The tooth most closely associated with each sinus was recorded. Data were analyzed using SPSS version 26. Descriptive statistics were calculated at patient and sinus levels. Associations between dental pathology and mucosal thickening were assessed using chi-square test. Multivariable logistic regression was performed with mucosal thickening as the dependent variable and dental pathologies, age, sex and root-sinus relationship as independent variables. A p-value <0.05 was considered statistically significant.

Results:

The study included 300 patients with mean age of 42.6 ± 13.8 years; 158 (52.7%) were male and 142 (47.3%) were female. Among 600 evaluated sinuses, at least one anatomical variation or mucosal abnormality was present in 374 sinuses (62.3%). Mucosal thickening greater than 2 mm was observed in 196 sinuses (32.7%). Sinus septa were present in 135 sinuses (22.5%), marked alveolar pneumatization in 118 (19.7%), retention cyst/polyp-like opacity in 52 (8.7%) and partial opacification in 31 (5.2%). The first molar region showed the highest frequency of root proximity to the sinus floor. Periapical lesions were present adjacent to 154 sinuses and mucosal thickening was observed in 86 of these sinuses (55.8%). Severe periodontal bone loss was associated with mucosal thickening in 48.3% of affected sinuses. In adjusted regression, periapical lesions, severe periodontal bone loss and direct root contact with the sinus floor were independently associated with mucosal thickening. Maxillary sinus variations, posterior dental findings and multivariable predictors of mucosal thickening are summarized in **Tables 1–3**.

Table 1: Distribution of maxillary sinus anatomical variations and abnormalities

Finding	Number of sinuses (n=600)	Percentage
Any sinus finding	374	62.3%
Mucosal thickening >2 mm	196	32.7%
Sinus septa	135	22.5%
Marked alveolar pneumatization	118	19.7%
Retention cyst/polyp-like opacity	52	8.7%
Partial sinus opacification	31	5.2%
Visible ostium obstruction	27	4.5%

Table 2: Association of posterior dental findings with mucosal thickening

Dental finding	Sinuses with finding	Mucosal thickening n (%)	p value
Periapical lesion	154	86 (55.8%)	<0.001
Endodontically treated tooth	132	58 (43.9%)	0.004
Severe periodontal bone loss	118	57 (48.3%)	<0.001
Root contact with sinus floor	190	82 (43.2%)	0.002
Root protrusion into sinus	54	28 (51.9%)	0.001
No posterior dental pathology	218	42 (19.3%)	Reference

Table 3: Multivariable predictors of maxillary sinus mucosal thickening

Predictor	Adjusted OR	95% CI	p value
Periapical lesion	3.12	2.01 to 4.86	<0.001
Severe periodontal bone loss	2.28	1.33 to 3.91	0.003
Endodontic treatment	1.46	0.91 to 2.35	0.116
Root contact/protrusion	2.06	1.18 to 3.59	0.011
Age >45 years	1.31	0.87 to 1.98	0.193
Male sex	1.18	0.79 to 1.77	0.413

Discussion:

The present CBCT study found that maxillary sinus variations and abnormalities were common in dental patients. Mucosal thickening was the most frequent abnormality, while septa and alveolar pneumatization were the most frequent anatomical variations. These findings are consistent with the high prevalence of incidental sinus findings reported in CBCT-based dental populations **[31, 32]**. Periapical lesions showed the strongest association with mucosal thickening. This supports the concept that apical inflammation of posterior maxillary teeth can stimulate localized Schneiderian membrane response, particularly when the root apex is in contact with or protrudes toward the sinus floor **[33, 34]**. Severe periodontal bone loss was also independently associated with mucosal thickening. Periodontal pockets and furcation defects in molars may provide a pathway for chronic inflammatory stimulus near the sinus floor. This finding highlights the need to consider both endodontic and periodontal sources when evaluating unilateral sinus mucosal changes **[35]**. Endodontic treatment showed a significant bivariate association but did not remain independently significant after adjustment. This suggests that endodontic status alone may be less important than persistent periapical disease, inadequate healing, or proximity to the sinus floor **[1, 2]**. Sinus septa were detected in approximately one-fifth of sinuses. This is clinically relevant for sinus augmentation because septa can increase membrane perforation risk and influence surgical window design. Pre-operative CBCT interpretation should therefore include systematic reporting of septa number, height, orientation and location **[5, 6]**. Mild mucosal thickening should not automatically be interpreted as odontogenic sinusitis. Radiographic changes need clinical correlation with nasal symptoms, dental symptoms, unilateral distribution, ostium involvement and response to dental

treatment. Overdiagnosis may lead to unnecessary medication or referral, whereas under-recognition may delay management of odontogenic infection **[7-10]**. CBCT interpretation must follow radiation protection principles. The scans in this study were taken for dental indications; therefore, the findings support comprehensive interpretation of existing images rather than prescribing CBCT solely for sinus screening. Incidental findings should be documented and communicated according to clinical relevance **[20-22]**. The limitations include retrospective design, absence of otolaryngological examination and lack of follow-up after dental treatment. Future prospective studies should combine dental diagnosis, rhinological assessment, symptom scoring and post-treatment imaging to clarify causality and resolution patterns **[23-30]**. The first molar region showed the greatest clinical relevance because its roots frequently approximate the sinus floor and are commonly affected by caries, endodontic treatment and periodontal furcation involvement. For this reason, CBCT interpretation in the posterior maxilla should not stop at implant bone height measurement. The radiologist and clinician should evaluate the tooth apex, lamina dura, sinus floor integrity, mucosal thickness and possible unilateral distribution of sinus change together. The association of root contact and protrusion with mucosal thickening suggests that anatomical proximity modifies the effect of dental infection. A small periapical lesion separated from the sinus by thick cortical bone may have less sinus impact than a similar lesion directly adjacent to a thin sinus floor. This finding supports reporting the spatial relationship between the lesion and sinus rather than simply describing the presence or absence of apical radiolucency. For implant dentistry, the findings reinforce the need to identify sinus septa and mucosal abnormalities before sinus augmentation. Septa can alter window design and pre-existing mucosal thickening may increase membrane handling difficulty. When mucosal disease appears extensive, unilateral, or associated with ostium obstruction, dental treatment planning should include medical or otolaryngology referral before elective sinus floor elevation. For endodontics, CBCT may clarify whether persistent symptoms after root canal treatment are related to missed canals, persistent apical periodontitis, vertical root fracture, or sinus mucosal response. However, CBCT findings should be integrated with pulp tests, percussion, periodontal probing and clinical history. Radiographic mucosal thickening alone should not lead to unnecessary tooth extraction or antibiotic prescription without confirming the odontogenic source. The study also highlights the value of structured CBCT reporting. A concise report that separates anatomical variants, mucosal findings, dental pathologies and their probable relationship can guide clinicians better than a descriptive list. Future work may develop reporting templates that grade odontogenic likelihood and recommend follow-up based on severity and clinical symptoms. The threshold used for mucosal thickening is also important. In this study, thickening greater than 2 mm was considered abnormal, but not every abnormal measurement requires active intervention. Localized thickening adjacent to a diseased root has greater odontogenic significance than diffuse bilateral thickening in a patient with allergic symptoms. Thus, interpretation should include morphology, location, symmetry and relationship to dental pathology. Patient communication is another practical aspect. Incidental sinus findings can cause anxiety if reported without context. Clinicians should explain that mild mucosal changes are common and often reversible, but dental sources of infection should be treated when present. A balanced explanation prevents both neglect of relevant odontogenic disease and unnecessary alarm over incidental radiographic changes. The results may also help prioritize treatment. When a periapical lesion is associated with localized sinus mucosal thickening, endodontic retreatment, apical surgery, or extraction should be planned before sinus augmentation or implant placement. Follow-up imaging may be considered only when symptoms persist or when the sinus finding may affect surgical access. Recent CBCT evidence is concordant with these findings. Kader *et al.* **[36]** reported frequent maxillary sinus mucosal thickening in posterior teeth with periapical pathology and emphasized the influence of the root-lesion relationship to the sinus floor. Kaimal and Patil **[37]** likewise found that periapical pathology, cortical bone destruction and closer root-sinus proximity were associated with maxillary sinus mucosal changes, supporting systematic evaluation of both dental and sinus structures on CBCT.

Conclusion:

Maxillary sinus anatomical variations and mucosal abnormalities were frequent on CBCT scans of dental patients. Periapical lesions, severe periodontal bone loss and direct root-sinus contact were independently associated with sinus mucosal thickening. Careful CBCT interpretation of both sinus and posterior dental structures is essential for implant planning, endodontic assessment, periodontal diagnosis and suspected odontogenic sinus involvement.

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