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Cone Beam Computed Tomography Analysis of the Correlation Between Gingival Biotype and Schneiderian Membrane

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ABSTRACT

The Schneiderian membrane plays a critical role in maxillary sinus health and implant planning. Although odontogenic and periodontal factors are known to influence membrane thickening, the role of the gingival phenotype remains unclear. **Objectives:** To evaluate the relationship between gingival biotype, gingival thickness, and Schneiderian membrane thickness and pathology using cone-beam computed tomography (CBCT). **Methods:** This analytical cross-sectional study included 96 CBCT scans obtained from Altamash Institute of Dental Medicine, Karachi. Gingival thickness was measured radiographically and classified as thin or thick biotype. Schneiderian membrane thickness was measured at corresponding posterior maxillary sites and categorized as normal (≤2 mm) or thickened (>2 mm). Sinus pathology was recorded. Independent-samples t-test, chi-square test, and Pearson correlation were applied ($p<0.005$). **Results:** Mean gingival thickness was 1.06 ± 0.18 mm, and mean membrane thickness was 2.23 ± 0.85 mm. Membrane thickening was observed in 61.5% of cases, while sinus pathology was present in 29.2%. No significant difference in membrane thickness was found between thin and thick biotypes (mean difference = 0.22 mm; $p=0.203$). Gingival biotype was not associated with membrane category ($p=0.340$) or sinus pathology ($p=0.107$). Gingival thickness showed a weak, non-significant correlation with membrane thickness ($r = 0.084$; $p=0.416$). **Conclusions:** Gingival phenotype was not significantly associated with Schneiderian membrane thickness or pathology. Sinus membrane alterations appear to be influenced predominantly by anatomical and odontogenic factors.

INTRODUCTION

The maxillary sinus is lined by the Schneiderian membrane, a specialized pseudostratified ciliated respiratory epithelium that plays a critical role in sinus physiology and mucociliary clearance. The thickness and integrity of this membrane are clinically important during sinus lift procedures, implant placement, and other surgical interventions involving the posterior maxilla [1]. Alterations in Schneiderian membrane thickness have been associated with odontogenic infections, periodontal disease, anatomical variations, and inflammatory processes, which may compromise surgical outcomes and implant success [2, 3]. Cone-beam computed tomography (CBCT) has emerged as a reliable three-dimensional imaging modality for evaluating maxillary sinus anatomy and pathology. Compared with conventional radiography, CBCT allows accurate measurement of sinus membrane thickness and identification of incidental findings such as mucosal thickening, retention cysts, and polypoid changes [4]. Recent CBCT-based studies have reported a high prevalence of incidental sinus findings in asymptomatic dental patients, with mucosal thickening being the most common radiographic presentation. These findings highlight the importance of understanding the factors influencing Schneiderian membrane alterations [5, 6].

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Several odontogenic and periodontal factors, including periapical lesions, periodontal bone loss, and proximity of posterior teeth to the sinus floor, have been implicated in sinus membrane thickening. Emerging evidence suggests that periodontal soft-tissue phenotype, particularly gingival biotype and gingival thickness, may reflect underlying tissue morphology and inflammatory susceptibility, potentially influencing adjacent sinus mucosa [7, 8]. Thin gingival phenotype has been associated with reduced tissue resilience and increased vulnerability to inflammation, while the thick phenotype is generally considered more resistant to mechanical and inflammatory challenges [9]. However, the relationship between gingival phenotype and Schneiderian membrane thickness remains controversial. Some CBCT-based investigations have reported positive correlations between thin gingival biotype and increased sinus membrane thickness, whereas others have found weak or non-significant associations. Differences in measurement techniques, biotype classification criteria, anatomical reference points, and population characteristics contribute to these inconsistencies. Moreover, most available evidence originates from non-South Asian populations, limiting the generalizability of findings to Pakistani dental patients, where periodontal disease burden and sinus pathology prevalence may differ.

Despite increasing interest in periodontal phenotype as a potential predictor of sinus membrane alterations, there remains a lack of standardized CBCT-based research evaluating this relationship within the Pakistani population. Furthermore, existing studies often demonstrate methodological heterogeneity, small sample sizes, and inconsistent operational definitions for membrane thickening. The objective was to determine whether gingival phenotype independently influences sinus mucosal thickness or whether Schneiderian membrane changes are primarily governed by broader anatomical and odontogenic determinants. By addressing this gap, the study seeks to contribute region-specific evidence to improve preoperative assessment and clinical decision-making in implant dentistry and sinus-related procedures. This study aimed to evaluate, using standardized CBCT measurements, the relationship between gingival biotype, gingival thickness, and Schneiderian membrane thickness and pathology in a Pakistani dental population.

METHODS

This analytical cross-sectional study was conducted at the Altamash Institute of Dental Medicine, Karachi, Pakistan, from 6th June 2024 to December 2024, using archived cone-beam computed tomography (CBCT) records to evaluate the relationship between gingival biotype, gingival thickness, and Schneiderian membrane thickness and pathology. Ethical approval was obtained from the Research Ethics and Review Committee of Altamash Institute of Dental Medicine (ERC Code: AIDM/ERC/06/2024/02; dated 6th June 2024). The study adhered to the Declaration of Helsinki. As archived CBCT scans were used, patient confidentiality was maintained through anonymization and removal of personal identifiers before analysis. Sample size was calculated using Fisher's Z transformation formula for correlation studies. Assuming a two-sided alpha of 0.05, a power of 80%, and an anticipated correlation coefficient of 0.30 based on previous radiographic periodontal sinus studies [9], the minimum required sample was 85. After adding a 10% margin for incomplete scans and exclusions, a total of 96 CBCT scans were included. A non-probability consecutive sampling technique was employed, and eligible scans were selected from the institutional radiology archive based on predefined inclusion and exclusion criteria. Inclusion criteria comprised patients aged 15 years and above, scans demonstrating adequate visualization of the posterior maxillary region and maxillary sinus, at least one measurable premolar or molar site, and diagnostic image quality with minimal artifacts. Exclusion criteria included previous maxillary sinus surgery or trauma, extensive sinus pathology obscuring standardized measurement sites, severe CBCT artifacts affecting anatomical landmarks, and the presence of maxillofacial tumors or conditions that could alter gingival architecture. Written informed consent was taken. All CBCT scans were acquired using the Planmeca ProMax 3D Mid system (Planmeca Oy, Helsinki, Finland), operating at 90 kVp and 10 mA, with a voxel size of 0.2 mm and a field of view of 8×8 cm, following standardized institutional imaging protocols. Digital Imaging and Communications in Medicine (DICOM) files were analyzed using calibrated radiographic software equipped with linear measurement tools. All measurements were performed under standardized viewing conditions to ensure consistency. A structured data collection proforma was specifically designed for this study after a literature review and expert consultation in oral radiology and periodontology [10]. The proforma included demographic variables (age and gender), gingival thickness, gingival biotype, Schneiderian membrane thickness, membrane category, sinus pathology (presence and type), and anatomical location (premolar or molar region). No previously validated questionnaire was used, as data were extracted directly from radiographic measurements. Gingival thickness was measured in millimeters at the mid-buccal aspect of the posterior maxillary region on cross-sectional CBCT slices at a standardized reference point. Gingival biotype was categorized as thin or thick based on radiographically measured gingival thickness using a predefined threshold. Schneiderian membrane thickness

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was measured perpendicular to the bony sinus floor at the point of maximum mucosal thickness corresponding to the evaluated site. Measurements were stratified according to premolar and molar regions. Membrane thickness was categorized as normal (≤2 mm) and thickened (>2 mm). This operational cut-off was adopted based on previously established CBCT diagnostic thresholds for sinus mucosal thickening reported in the literature [11]. Sinus pathology was recorded as present or absent, and when present, classified as retention cyst, polypoid mucosal change, or diffuse mucosal thickening based on CBCT morphology. To ensure measurement reliability, examiner calibration was conducted before data extraction. Approximately 10–15% of scans were reassessed to determine intra-observer reliability, and an independent assessor evaluated a subset for inter-observer reliability. Intraclass correlation coefficient (ICC) was calculated for continuous variables, including gingival thickness and Schneiderian membrane thickness. All eligible scans were assigned unique study identification numbers. Data were entered into a computerized database and verified through random cross-checking.

Statistical analysis was performed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Normality was assessed using histograms, Q-Q plots, and the Shapiro–Wilk test. Since variables were normally distributed ($p>0.005$), parametric tests were applied. An independent-samples t-test was used to compare mean membrane thickness between gingival biotypes. Chi-square test was used to assess associations between gingival biotype and membrane category as well as sinus pathology. Pearson correlation coefficient (r) was calculated to evaluate the relationship between gingival thickness and Schneiderian membrane thickness. Statistical significance was set at $p<0.005$.

RESULTS

Participant demographics and scan characteristics are summarized. A total of 96 participants were included, with a mean age of 36.92 ± 13.59 years. Females comprised 50 (52.1%) and males 46 (47.9%). CBCT measurements were equally distributed between the left and right sides. The majority of measurements were recorded in the molar region (66.7%). Periodontal status showed a relatively balanced distribution, with 31.3% healthy, 35.4% gingivitis, and 33.3% periodontitis cases (Table 1).

Table 1: Baseline Characteristics of the Study Participants (n=96)

Variables	Overall (n=96), n (%)
Age (Years)	
Mean ± SD	36.92 ± 13.59
Gender	
Female	50 (52.1%)
Male	46 (47.9%)
Side Examined	
Left	48 (50.0%)
Right	48 (50.0%)
Region Measured	
Molar	64 (66.7%)
Premolar	32 (33.3%)
Periodontal Status	
Healthy	30 (31.3%)
Gingivitis	34 (35.4%)
Periodontitis	32 (33.3%)

Gingival phenotype findings are presented. A slight predominance of thin gingival biotype (52.1%) was observed compared to thick biotype (47.9%). The mean gingival thickness was 1.06 ± 0.18 mm, ranging from 0.72 to 1.44 mm. Mean gingival thickness was comparable between thin (1.05 ± 0.19 mm) and thick (1.07 ± 0.17 mm) biotypes (Table 2).

Table 2: Gingival Biotype and Gingival Thickness (n=96)

Variables	n (%) / Mean ± SD
Gingival Biotype	
Thin	50 (52.1%)
Thick	46 (47.9%)
Gingival thickness (mm)	1.06 ± 0.18
Gingival thickness (mm), min–max	0.72 – 1.44
Gingival Thickness by Biotype (mm)	
Thin biotype	1.05 ± 0.19
Thick biotype	1.07 ± 0.17

Schneiderian membrane characteristics are shown. The mean membrane thickness was 2.23 ± 0.85 mm (range 0.33–3.99 mm). Membrane thickening (>2 mm) was observed in 61.5% of cases. Sinus pathology was identified in 29.2% of participants, with diffuse mucosal thickening being the most frequent finding. Membrane thickness was greater in the molar region (2.48 ± 0.81 mm) compared to the premolar region (1.85 ± 0.77 mm) (Table 3).

Table 3: Schneiderian Membrane Characteristics (n=96)

Variables	n (%) / Mean ± SD
Membrane Thickness (mm)	2.23 ± 0.85
Membrane Thickness (mm), min–max	0.33 – 3.99
Membrane Category	
Normal (≤2 mm)	37 (38.5%)
Thickened (>2 mm)	59 (61.5%)
Sinus Pathology	
Yes	28 (29.2%)
No	68 (70.8%)
Pathology Type	
Retention Cyst	10 (10.4%)
Polypoid Mucosal Change	6 (6.3%)

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Diffuse Mucosal Thickening	12 (12.5%)
Membrane Thickness by Location (mm)	
Premolar Region	1.85 ± 0.77
Molar Region	2.48 ± 0.81

Comparison of Schneiderian membrane findings between gingival biotypes is presented. Mean membrane thickness did not differ significantly between thin and thick biotypes (2.34 ± 0.72 mm vs 2.12 ± 0.97 mm). The mean difference was 0.22 mm (95% CI: −0.12 to 0.56; t (94) = 1.28; p=0.203). The effect size was small (Cohen's d = 0.26). Gingival biotype was not significantly associated with membrane category (χ^2 (1) = 0.91, p=0.340; Cramer's V = 0.097). Similarly, no significant association was observed between gingival biotype and sinus pathology (χ^2 (1) = 2.59, p=0.107; Cramer's V = 0.164)(Table 4).

Table 4: Comparison of Schneiderian Membrane Findings Between Gingival Biotypes (n=96)

Outcomes	Thin (n=50)	Thick (n=46)	p-value
Membrane Thickness (mm), Mean ± SD	2.34 ± 0.72	2.12 ± 0.97	0.203
Membrane Category, n (%)			
Normal	17 (34.0)	20 (43.5)	0.340
Thickened	33 (66.0)	26 (56.5)	
Sinus Pathology, n (%)			
Yes	11 (22.0)	17 (37.0)	0.107
No	39 (78.0)	29 (63.0)	

Correlation analysis between gingival thickness and Schneiderian membrane thickness is presented. Pearson correlation demonstrated a weak, non-significant association (r = 0.084; 95% CI: −0.118 to 0.278; p=0.416) (Table 5).

Table 5: Correlation Between Gingival Thickness and Schneiderian Membrane Thickness (n=96)

Variable	Pearson's r	95% CI	p-value
Gingival thickness vs membrane thickness	0.084	−0.118 to 0.278	0.416

DISCUSSION

The present CBCT-based cross-sectional study demonstrated that the gingival biotype was not significantly associated with Schneiderian membrane thickness. Furthermore, gingival thickness showed only a weak and non-significant correlation with membrane thickness (r = 0.084; p=0.416). These findings suggest that sinus mucosal alterations are likely influenced by multifactorial anatomical and odontogenic determinants rather than the gingival phenotype alone [12]. This study findings are consistent with previous CBCT-based investigations reporting weak or non-reproducible associations between periodontal phenotype and sinus membrane thickness. De Souza Fernandes *et al.* similarly observed only a minimal association between gingival biotype and maxillary sinus membrane thickness, concluding that anatomical and odontogenic factors may play a more dominant role [13]. Likewise, Diaz *et al.* in a systematic review, highlighted substantial methodological heterogeneity across studies, limiting definitive conclusions regarding the impact of periodontal phenotype on Schneiderian membrane thickness [10]. In contrast, some studies have reported positive correlations between thin gingival phenotype and increased membrane thickness. For example, Javed *et al.* demonstrated a statistically significant association in a Pakistani cohort [14]. However, the discrepancy between their findings and ours may be attributed to differences in biotype classification criteria, radiographic measurement landmarks, regional sampling, and variation in periodontal disease severity among study populations. Another important finding of our study was the significantly greater membrane thickness observed in the molar region compared to the premolar region. This supports the concept that posterior maxillary teeth, particularly molars, exert a stronger odontogenic influence on sinus mucosa due to their anatomical proximity to the sinus floor. Sökmen and Sökmen similarly reported that root proximity and periodontal parameters significantly influenced Schneiderian membrane thickness [15]. Saquib *et al.* also emphasized that regional anatomical variations and lateral sinus wall thickness contribute substantially to mucosal thickness variability [16]. Although the gingival phenotype did not demonstrate a significant association, sinus membrane thickening and incidental sinus pathology were frequently observed in our study. Membrane thickening (>2 mm) was present in 61.5% of cases, while sinus pathology was identified in 29.2%. These findings are comparable with regional CBCT prevalence studies [17]. İspir *et al.* reported mucosal thickening and retention cysts as common incidental findings in the asymptomatic dental population [17]. Similarly, Madfa *et al.* observed that radiographic mucosal thickening on CBCT does not necessarily indicate clinically significant sinus disease [18]. Existing literature also suggests that periodontal bone loss and periapical pathology are more strongly associated with sinus membrane thickening than with the gingival phenotype. Eksi and Seker demonstrated a significant association between the severity of periodontal bone loss and Schneiderian membrane thickness [19]. while AlRowis *et al.* reported a strong correlation between periodontitis and maxillary sinus changes on CBCT [20]. These findings reinforce our observation that sinus membrane alterations are multifactorial and may be more closely related to inflammatory and anatomical factors than to isolated soft-tissue phenotype. Clinically, this study's results suggest that CBCT-detected Schneiderian membrane thickening should be interpreted within a broader anatomical and odontogenic context rather than relying solely on gingival phenotype assessment. This has

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particular relevance in sinus lift planning and implant placement in the posterior maxilla, where accurate risk stratification is essential.

Current study has certain limitations. First, its cross-sectional design precludes causal inference. Second, variables such as periapical status, smoking history, sinus ostium patency, and detailed periodontal bone loss measurements were not included, which may act as potential confounders. Third, gingival biotype classification was based on radiographic measurement rather than clinical translucency assessment. Future multicenter longitudinal studies with larger samples incorporating detailed periodontal parameters, anatomical sinus variations, and additional inflammatory markers are recommended to better elucidate the independent role of gingival phenotype in sinus membrane alterations. Standardization of CBCT measurement protocols and biotype classification criteria would further enhance comparability across studies.

CONCLUSIONS

In this CBCT-based study of 96 participants, gingival biotype and gingival thickness were not significantly associated with Schneiderian membrane thickness. Sinus membrane thickening and incidental sinus pathology were common, particularly in the molar region, suggesting a stronger influence of anatomical and odontogenic factors than gingival phenotype alone. These findings emphasize the importance of comprehensive radiographic assessment in implant and sinus-related procedures.

Authors' Contribution

Conceptualization: HS
Methodology: HS, ZHC, V, KK
Formal analysis: ZHC, SAJ
Writing and Drafting: HS, ZHC, ZAK, V, SAJ, KK
Review and Editing: HS, ZHC, ZAK, V, SAJ, KK

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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