Influence of the Periapical Status of the Posterior Maxillary Teeth on the Width of the Schneiderian Membrane of the Maxillary Sinus Mucosa

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Abstract: Background: Various parameters are known to affect the amount and type of mucosal thickening. The aim of this retrospective study was to investigate these effects through a survey of cone-beam computed tomography (CBCT) images. CBCT scans of 150 patients, which included the area of the MS and maxillary teeth (canine, first premolar, second premolar, first molar, second molar, and third molar), were evaluated retrospectively for the presence of sinus mucosal thickening. The parameters evaluated as possible causes of mucosal thickening were age, sex, tooth type, proximity to the maxillary sinus, endodontic treatment, and periapical lesion. Descriptive statistics and multiple logistic regression were used to analyze the data. A total of 28% of the teeth presented with mucosal thickening, which was associated with periapical lesions in 57.1% of 77 cases. The size of the lesion was the only parameter that was found to be significantly connected to the presence of mucosal thickness. More than 50% of teeth with periapical lesions in the posterior maxilla exhibited mucosal thickening. Other parameters such as age, sex, and the position of the root tips in relation to the MS floor did not influence the probability of developing mucosal thickening.

Keywords: maxillary sinus; Schneiderian membrane; CBCT; dental; periapical lesions

1. Introduction

The maxillary sinus (MS) cavity is lined with the Schneiderian membrane, which is a pseudostratified columnar ciliated epithelium with similar characteristics to the respiratory epithelium and the membrane. The thickness of this membrane varies between 0.13 and 0.5 mm [1].

The roots of the maxillary posterior dentition are in close proximity to the floor of the sinus, and they share a common innervation [2,3]. Periapical lesions may develop in teeth whose root apices are close to, or protrude into, the maxillary sinuses. This can cause inflammatory changes in the mucosal lining and result in the development of sinusitis [4,5].

Approximately 10% to 86% of all cases of maxillary sinusitis are caused by an odontogenic infection [6–9]. In 1943, Bauer [10] was the first to report that periapical inflammation can affect the sinus mucosa, even without perforation of the cortical bone of the sinus floor. Infection and inflammatory mediators may spread to the MS [10].

Mild MS mucosal thickening is a normal finding in persons without any symptoms of sinusitis [11]. Rak et al. found that mucosal thickening was greater than 2 mm in most patients with maxillary sinusitis, and a value of more than 3 mm was an important indicator of a pathologic condition [12].

Two-dimensional intraoral periapical radiography generally provides limited data about the character of periapical lesions. This is a particular problem in the maxillary
molars due to the superimposition of adjacent structures such as the palatal root or the zygomatic bone [13–15].

Panoramic radiography (OPG) is usually used for the diagnosis of orofacial pain, however, panoramic images have only a limited value for the diagnosis of sinus lesions [16].

Cone beam computed tomography (CBCT) is often used for imaging of the MS [17,18]. CBCT has a lower radiation dose [19], higher resolution, and lower scanning time [7], it also allows three-dimensional cross-sectional imaging, which eliminates distortion and superposition [20]. In this context, a number of studies have reported CBCT to be suitable for the evaluation of the maxillary sinuses and adjacent teeth [7,21–25].

A number of studies have compared OPG and CBCT for diagnosing sinus diseases, as well as for evaluating the anatomical relationships of the posterior teeth and their distance to the maxillary sinus floor. Panoramic imaging has a low efficacy in the diagnosis of sinus disease [16,26] and a history of unreliable diagnoses when evaluating the distance between the sinus floor and roots of the maxillary teeth [27].

The use of plain films, such as Waters’ view (occipitomental view) and Caldwell’s view (occipitofrontal view), is a traditional method for evaluating the sinonasal area. These methods have the advantage of availability, ease of use, low radiation dose, and low cost [28–30]. A study by Ebrahimnejad et al. [31] comparing the diagnostic efficacy of digital Waters’ and Caldwell’s radiographic views in measuring the sinonasal area concluded that the digital Waters’ view is a reliable modality for maxillary sinus evaluation, with a superior ability to detect healthy cases [31].

One disadvantage of CBCT is that the soft tissue contrast resolution is inferior to that of magnetic resonance imaging (MRI), which can also provide precise sinus anatomical characterization, as well as a differentiation between inflammatory sinus alterations [32]. However, despite this capability, a number of studies have reported that the efficacy of assessing maxillary sinus pathology using MRI remains controversial [33,34].

Overall, the high radiation dose and financial cost of both CT and CBCT imaging necessitate a justification of their use to evaluate abnormalities of the maxillary sinuses [8].

The purpose of this study was to use CBCT to analyze the correlation between the periapical status of maxillary posterior teeth and the status of the MS mucosa.

2. Materials and Methods

This study was approved by the Tel Aviv University ethics committee (IRB reference number 167.19).

The dental records of the patients treated in the university clinic between the years 2019 and 2020 were screened for the presence of CBCT scans that included the area of the MS and maxillary teeth (canine, first premolar, second premolar, first molar, second molar, and third molar). All the scans were done using a ProMax 3Ds (Planmeca OY, Helsinki, Finland) with a small field of view (19–44 mSV) and a 0.2-mm voxel size. Operating parameters were set at 8.0 mA and 84 kV with a 12-s exposure time. Operating parameters were set at 8.0 mA and 84 kV with a 12-s exposure time. Operating parameters were set at 8.0 mA and 84 kV with a 12-s exposure time. Operating parameters were set at 8.0 mA and 84 kV with a 12-s exposure time. All the CBCT scans were evaluated by two calibrated examiners (E.D and I.T) according to the following exclusion criteria.

The exclusion criteria were as follows:
1. Radiographic evidence of sinus pathology (any radiographic findings/radiopaque areas except for the mucosal thickening)
2. Edentulous maxilla.
3. Dental implants in the posterior maxilla.
4. Individuals below 18 years of age
5. Low-quality images (according to the calibrated examiners, in cases where it was impossible to clearly evaluate the periapical status of the teeth or the sinus mucosa due to scattering or poor contrast) were excluded.
6. Images with artifacts.

Demographic data, age, and tooth status (with or without endodontic treatment) were recorded.
The periapical status was graded as follows to provide a periapical index (PAI), as described previously [35]:

0. Intact periapical bone structures
1. Maximum diameter of periapical radiolucency 0.5–1 mm
2. Maximum diameter of periapical radiolucency 1–2 mm
3. Maximum diameter of periapical radiolucency 2–4 mm
4. Maximum diameter of periapical radiolucency 4–8 mm
5. Maximum diameter of periapical radiolucency >8 mm

Score (n) E * Expansion of periapical cortical bone
Score (n) D * Destruction of periapical cortical bone

The positions of the root tips in relation to the sinus floor were categorized according to Tian et al. [3].

1. Type IS: The root tips extend above/inside the MS floor.
2. Type CO: The root is in contact with the MS floor.
3. Type OS: The root extends below/outside the sinus floor.

The vertical relationship between the root of the maxillary premolar and molar and the MS floor was assessed concomitantly in the sagittal, coronal, and axial CBCT planes. We measured the distance to the sinus of each root of the molar or the premolar and considered only one root, with the maximum proximity to the sinus. The shortest vertical/oblique distance from the root apex of the premolar and molar to the closest border of the MS was measured, and the lower value of the two was recorded [3].

The MS mucosa was divided into five classes according to the maximal mucosal thickness present in the exposed MS adjacent to the involved tooth:

0. normal (no mucosal thickness).
1. up to 1 mm
2. up to 2 mm
3. up to 3 mm
4. 4 mm or more

A thickness of 3 mm or more was considered mucosal thickening [12].

Image evaluation: The CBCT scans were evaluated in a room with the lights dimmed on a 24-inch LED monitor (Dell U2412M) with a resolution of 1920 × 1200 pixels and 0.27 mm pixel pitch (Figure 1).

![Image of a CBCT scan](image_url)

**Figure 1.** A representative image of a CBCT scan of the second maxillary premolar and mucosal thickening measurements.

**Statistics**

Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA).
Demographic data were analyzed using descriptive analysis, and linear and logistic regression analysis was used to investigate the correlation between study variables affecting the amount and type of MT. The level of significance was set at $p = 0.05$.

3. Results

Among the 150 CBCT scans sampled, 77 scans containing at least one MS were included in the study population. The medical history of all the included patients was non-contributory. These involved a total of 275 teeth from individuals with a mean age of $45.9 \pm 29$ years. The study included 115 teeth from males (58%) and 160 teeth from females (42%) (Table 1).

Table 1. Study Demographics.

| Sex     | Age (years) | Total |
|---------|-------------|-------|
|         | 18–30 | 31–50 | >51 | |
| Male    | 28/275 (10.1%) | 16/275 (5.8%) | 72/275 (26.1%) | 42% |
| Female  | 38/275 (13.8%) | 73/275 (26.5%) | 48/275 (17.7%) | 58% |

No correlation was found between sex, age, and MS mucosal thickening. Seventy-seven teeth (28%) presented with mucosal thickening >2 mm (class 3 or higher). The prevalence of MT >2 mm was almost homogenous amongst males (40/77—51.9%) and females (37/77—48.1%). The overall gender related difference in MT was not significant ($p > 0.05$).

Among the teeth presenting with an MT score of three or more: 3 were canines, 13 were first premolars, 11 were second premolars, 28 were first molars, 20 were second molars, and 1 was a third molar (Table 2).

Table 2. Tooth type and the relationship with mucosal thickness.

| Tooth Type | Percent of Total | Mucosal Thickening |
|------------|------------------|--------------------|
|            | 0     | 1    | 2    | 3    | 4    |
| Canine     | 19.7% | 44/275 | 3/275 | 4/275 | 2/275 | 1/275 |
| 1st premolar| 23.6% | 28/275 | 14/275 | 10/275 | 3/275 | 10/275 |
| 2nd premolar| 16%   | 5/275  | 14/275 | 14/275 | 4/275 | 7/275 |
| 1st molar  | 18.9% | 5/275  | 10/275 | 9/275  | 14/275 | 14/275 |
| 2nd molar  | 18%   | 5/275  | 9/275  | 16/275 | 10/275 | 10/275 |
| 3rd molar  | 3.8%  | 4/275  | 4/275  | 1/275  | 1/275 | 0/275 |

A non-intact CBCT PAI (over 0.5 mm, score 1 or more) was found in 189/275 teeth (68.7%), of which, 68 teeth also presented with MT (68/189—32.8%, $p > 0.05$).

A total of 67/275 (24.3%) teeth presented with apical periodontitis (CBCT PAI score 3 or more).

Out of 77 cases of mucosal thickening, 44 (57.1%) cases were associated with periapical lesions (CBCT PAI 3 or more, Table 3, $p < 0.05$).
Table 3. Size of periapical lesion and the relationship to mucosal thickness.

| Size of PA Lesion (CBCT PAI) | Percent of Total | 0      | 1      | 2      | 3      | 4      |
|-----------------------------|------------------|--------|--------|--------|--------|--------|
| 0                           | 31.5%            | 46/275 | 19/275 | 13/274 | 2/275  | 6/275  |
|                             | (16.9%)          | (6.9%) | (4.9%) | (0.7%) | (2.1%) |
| 1                           | 27.8%            | 23/275 | 22/275 | 26/275 | 5/275  | 1/275  |
|                             | (8.3%)           | (8%)   | (9.3%) | (1.8%) | (0.4%) |
| 2                           | 16.4%            | 9/275  | 6/275  | 12/275 | 5/275  | 13/274 |
|                             | (3.2%)           | (2.1%) | (4.4%) | (1.8%) | (4.9%) |
| 3                           | 14.6%            | 7/275  | 6/275  | 2/275  | 13/274 | 12/275 |
|                             | (2.5%)           | (2.1%) | (0.7%) | (4.9%) | (4.4%) |
| 4                           | 7.6%             | 4/275  | 1/275  | 1/275  | 7/275  | 8/275  |
|                             | (1.4%)           | (0.4%) | (0.4%) | (2.5%) | (2.9%) |
| 5                           | 2.1%             | 2/275  | 0/275  | 0/275  | 2/275  | 2/275  |
|                             | (0.7%)           | (0%)   | (0%)   | (0.7%) | (0.7%) |

The size of the lesion was the only parameter that was found to be significantly connected to the presence of mucosal thickness (Table 3, \( p < 0.05 \)).

There was no correlation between the position of the root tip and the sinus floor. In the majority of the teeth examined, the root extended below/outside the sinus floor, OS-60.5%. Only 7.4% of all teeth presented with the tip of the root inside the MS (Table 4).

Table 4. The anatomical relationship between the sinus floor and the root tips of adjacent teeth, and the maxillary mucosal thickness.

| Maxillary Sinus Proximity | Percent of Total | Mucosal Thickening |
|--------------------------|------------------|--------------------|
|                          |                  | 0      | 1      | 2      | 3      | 4      |
| OS                       | 60.5%            | 24.6%  | 13.1%  | 10.8%  | 5.8%   | 6.2%   |
| CS                       | 32.1%            | 7.4%   | 4.9%   | 8.5%   | 5.8%   | 5.5%   |
| IS                       | 7.4%             | 1%     | 1.5%   | 0.4%   | 0.8%   | 3.7%   |

4. Discussion

The present study used CBCT images to evaluate the effect of various factors associated with periapical lesions on the amount of mucosal thickness: conditions such as chronic sinusitis, pseudocysts, retention cysts, and mucocele have all been reported to have a major effect on the basal membrane of the MS [36–38]. In addition, local and patient-related factors including age, gender, smoking, and periodontal status may also affect the thickness of MS membrane [7,39,40].

CBCT imaging can be useful in diagnosing the etiology and extent of an endodontic pathology and the involved sinus [41]. Maillet et al. [42] used CBCT scanning to report that odontogenic sinusitis can be identified as localized thickening of the mucous membrane of the MS associated with dental lesions. Recent reports of the relationship between maxillary teeth and the MS [23,25,43] differed from our study, in that Gürhan et al. [23] included only cases with mucosal thickness and excluded other areas. In addition, they did not measure the distance between the root apices and the sinus floor, while Souza-Nunes [25] only evaluated endodontically treated teeth. Similarly, Garcia-Font et al. [43] only included teeth with periapical pathology. Even though mucosal thickening is usually more pronounced in the region of teeth with periapical pathology [44], and the degree of apical periodontitis has been positively correlated with sinus mucosal thickening [6,7], Block et al. [21] reported sinus membrane thickening in 46.7% of patients, with an almost equal association with unhealthy and healthy teeth. For our study, we decided to include both treated and non-treated teeth, and the condition of the tooth was not an exclusion criterion. It is clinically
important that the mucosal changes maybe not resolve following the extraction or treatment of the involved teeth [21,30].

Patients with systemic diseases were excluded from this study. While, on the one hand, this may be a limitation of this investigation, on the other hand it reduced the variability and helped with the standardization of the study.

The percentage of teeth with MS involvement seen in our study was lower than the 38.04–70.52% reported previously [7,21,22,25,45]. This is probably due to our inclusion of canine teeth. The roots of the maxillary premolars, molars, and in some cases the canine teeth have a close relationship with the MS, and may even protrude into it [2,46,47]. In our study the teeth most frequently associated with mucosal thickening (class >2) were the maxillary first molars, followed by maxillary second molars and the third molars. The canines were rarely associated with the maxillary sinus.

Other differences could stem from the methods of measuring MS membrane thickness used in the various studies. Nunes (2016) described six categories of the MS membrane, including a number of abnormalities, such as sinus polyp, antral pseudocyst, nonspecific opacification, periostitis, and antrolith [45]. Cases with such sinus abnormalities were excluded from our study.

Although many authors in the literature have accepted a mucosal thickness >2 mm as a sign of sinus pathosis [7,22,41,48–50], we employed the categories of Rak et al. [12], who concluded that mucosal thickening of up to 3 mm is common and lacks clinical significance [12].

Periapical status has also been evaluated by a variety of scales. Gomes et al. described a periapical lesion as an at least 0.5 mm thick area of apical radiolucency associated with the apical portion of the root or ligament space [51]. Bajoria et al. [52] divided the periapical status of teeth in CBCT scans into three categories, while Khorramdel et al. and others evaluated the periapical status of teeth from CBCT scans using the periapical index scoring created by Orstavik (1986) and based on periapical two dimensional films [7,24]. In his study, de Souza-Nunes used a new classification system, called the periapical and endodontic status scale (PESS). This is based on the periapical index (COPI), which was proposed for the classification of periapical lesions in teeth with apical periodontitis, and the endodontically treated tooth index (ETTI) for the assessment of the quality of endodontic treatment by CBCT [23,53]. It should be noted that evaluation of the quality of root canal treatment by means of CBCT scans can be problematic due to artifacts (1,22). The extrusion of endodontic materials inside the sinus may result in inflammatory reactions of the sinus mucosa (1). While the root canal sealers are considered biocompatible, proper root canal instrumentation and sealing is important in order to prevent sinus pathologies of endodontic origin (22).

In this study we evaluated the periapical status of teeth with the six category CBCT PAI score described by Esterala et al. [35]. We consider that the multiple categories are important in grading the severity of the periapical lesion, in contrast to the dichotomy categorization used in Gomes’ study [51]. One of the findings in our study was the correlation between the size of the periapical lesion and the degree of the thickening of the mucosal membrane.

Our results revealed a high frequency of periapical alterations in endodontically treated teeth (54%). The presence of periapical radiolucency in CBCT may present the ongoing healing of a previously larger lesion; other studies that reported similar results attributed the high rate of periapical lesions to failure to follow recommended technical criteria [52,54,55].

5. Conclusions

Within the limitations of this study, two main conclusions can be drawn:

1. Age, sex of the patient, or the position of the root tips in relation to the MS floor did not influence the likelihood of MS development.
2. Among maxillary posterior teeth with apical periodontitis, more than 50% had MS mucosal thickening, and the prevalence of MS increased with the size of the lesion.

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Informed Consent Statement: Patient consent was waived due to the study being done on anonymous radiographic data without any ability to connect it to the specific patient.

Data Availability Statement: Data available in a publicly accessible repository. The data presented in this study are openly available in [repository name e.g., FigShare] at [doi], reference number [reference number].

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