Original Paper

The Relationship between Maxillary Sinus Lateral Wall Thickness, Alveolar Bone Loss, and Demographic Variables: A Cross-Sectional Cone-Beam Computerized Tomography Study

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Significance of the Study

- The analysis of cone-beam computerized tomography images could be an effective and accurate method for evaluating the possible relationship between sinus lateral wall thickness and periodontal bone loss. It may also be used to prevent possible complication during maxillary sinus surgery.

Abstract

Objectives: Sinus floor elevation and augmentation surgery is widely used as a reliable procedure to increase insufficient bone height in the posterior maxillary area. The purpose of the present clinical study was to determine the associations between periodontal bone loss (PBL), maxillary sinus lateral bone wall thickness, age, and gender using cone-beam computerized tomography (CBCT). ***Materials and Methods:*** The current retrospective study consists of 716 maxillary sinus CBCT images of 358 patients. The CBCT scans were assessed to detect the relationship between lateral wall thickness and PBL. ANOVA and Student *t* test analysis were used to determine the influence of PBL on sinus lateral wall thickness. ***Results:*** Sinus lateral wall thickness was significantly associated with PBL ($p < 0.05$) at 3, 13, and 15 mm height. There was no significant association between lateral wall thickness and gender ($p > 0.05$). However, there was a significant association between lateral wall thickness at 3 and 13 mm and age ($p < 0.05$). There were significant associations between PBL and age ($p < 0.001$), and PBL and gender ($p < 0.05$). ***Conclusions:*** PBL might have an association with maxillary sinus lateral bone wall thickness. Further studies are needed to confirm this possible relationship.

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Introduction

Dental implants are commonly used to rehabilitate edentulous areas such as the posterior maxilla [1]. Dental implant therapy of the posterior maxilla is often problematic due to the insufficient height and width of the alveolar bone ridge. Extension of the maxillary sinus into the alveo-

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lar crest area after tooth extraction is also a main concern [2, 3]. Sinus floor elevation and augmentation surgery are a widely used predictable procedure for increasing insufficient bone height in the posterior maxillary area [4–6].

Maxillary sinus augmentation is performed by using two different surgical approaches, the lateral window approach and the crestal approach [7]. Both techniques have shown acceptable results; however, the lateral window approach is still considered more predictable in terms of outcome and safety, especially for cases with minimal bone height [8, 9]. In the lateral window approach, an entrance window is made in the maxillary sinus lateral wall and the sinus membrane is carefully lifted from the sinus floor to create a space between the membrane and the sinus floor to place the bone grafting material [2, 10]. This sinus-lifting procedure is generally considered to be safe and has a low complication rate [11]. Nevertheless, the most common complication of this surgical technique is the perforation of the Schneiderian membrane [12, 13]. It is therefore critical to predict possible sinus membrane perforations before the operation to avoid complications [2]. Furthermore, it is important to accurately determine the thickness of the lateral sinus wall, and it is necessary to make a lateral wall osteotomy to open a window to the maxillary sinus [1].

Cone-beam computerized tomography (CBCT) is considered the gold standard technique for diagnosis and treatment planning in dentistry [14, 15], including many advantages such as lower radiation doses, high accuracy, and three-dimensional measurements [16, 17]. CBCT evaluation has allowed the clinicians a correct evaluation of soft and hard tissues and helps eliminate the distortion and superposition related to teeth and the surrounding structures [18, 19]. A limited number of studies have evaluated the lateral sinus wall thickness [7, 20]. Different local or systemic factors could affect lateral wall thickness, such as periodontal disease [1, 21]. However, to the best of our knowledge, there are no reports published in English about the relationship between periodontal bone loss (PBL) and the lateral wall thickness of the maxillary sinus. Therefore, the aim of the present clinical study was to explore the associations between PBL, lateral wall thickness, age, and gender.

Materials and Methods

Study Samples
The present retrospective study, approved by the Institutional Review Board, evaluated CBCT images of 716 maxillary sinuses from 358 subjects (160 females and 198 males with a mean age of 36.66 ± 13.51 years, ranging from 18 to 86 years). These CBCT images obtained from patients who visited the Department of Dento-Maxillofacial Radiology 2009–2012. Patients seeking dental and/or oral treatments (i.e., dental implants, endodontic procedures, oral/periodontal surgery, orthodontics, and oral diseases) were included. Exclusion criteria consisted of the presence of metallic artifacts, sinus pathology, jaw fracture, grafted sinuses, and nondiagnostic, low-resolution quality of CBCT images. The CBCT scans were assessed to detect the thickness of the maxillary sinus lateral wall and PBL. All these parameters were recorded from the right and left maxillary sinuses.

CBCT Image Analysis
CBCT images were obtained by using a CBCT scanner (I-CAT vision TM; Imaging Science International, Hatfield, PA, USA) at 120 kVp and 18.54 mA, with an exposure time of 8–9 s. The voxel size of the images was 0.25–0.4. Image analysis was performed with the KaVo 3D eXam Vision (KaVo Dental GmbH, Biberach/Riss, Germany) software on a multiplanar reconstruction window in which the axial, coronal, and sagittal planes could be visualized in 0.2-mm intervals. All images were reviewed, and all measurements were performed by one calibrated examiner (T.T.Y.).

CBCT Analysis
Assessment of PBL
Panoramic view was used to evaluate PBL in CBCT images. The percentage of normal periodontal bone height was calculated at mesial and distal sides of each tooth. To assess the level of PBL, the distance between the point 2 mm under the cemento-enamel junction and the upper point of the alveolar bone was measured. The extent of PBL was classified as described before [22]: Class 1: normal to mild, <25% bone loss; Class 2: moderate, 25–50% bone loss; Class 3: severe, >50% bone loss.

Assessment of Sinus Lateral Wall Thickness
Sinus lateral wall thickness measured from the maxillary 1st molar region in the 716 CBCT images. The cross-sectional view was used to identify sinus lateral wall thickness. Thickness of the sinus lateral wall 3 and 13 mm above the sinus floor, and 15 mm above the alveolar ridge were measured (Fig. 1) [23].

Statistical Analyses
The SPSS 21 (SPSS Inc., Chicago, IL, USA) software program was used for statistical analysis. Variables were described as mean ± standard deviation (SD). A significant difference among the mean values of the lateral wall thickness of 3 points and PBL were tested by ANOVA. If there were significant differences among the subgroups of these parameters, Tukey's method for post hoc analysis was performed. Pearson's correlation test was used to detect the correlation between the PBL and lateral wall thickness. Differences of gender, right, and left sides were performed using Student's t test. ANOVA was used to evaluate differences of age. $p < 0.05$ was considered statistically significant.

Results

Study Sample
The CBCT images of 716 maxillary sinuses of 358 included patients (160 females and 198 males, mean age
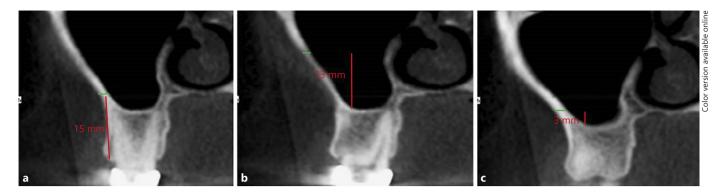
Fig. 1. Cross-sectional CBCT images showing sinus lateral wall thickness measurements at 15 mm (**a**), 13 mm (**b**), and 3 mm (**c**).

Table 1. Mean and standard deviation of the lateral wall thickness of the maxillary sinus in three reference points, according to gender

Reference point	Male			Female			p^*
	n	mean	SD	n	mean	SD	
Lateral wall thickness 3 mm from sinus floor	396	2.30	1.19	320	2.27	1.06	0.736
Lateral wall thickness 13 mm from sinus floor	396	4.36	2.55	320	4.55	2.46	0.334
Lateral wall thickness 15 mm from alveolar crest	396	2.96	1.76	320	2.91	1.76	0.739

SD, standard deviation. * $p < 0.05$ presents statistical significance.

Table 2. Mean and standard deviation of the lateral wall thickness of the maxillary sinus in three reference points, according to age groups

Reference point	<25 years			25–50 years			>55 years		
	n	mean	SD	n	mean	SD	n	mean	SD
Lateral wall thickness 3 mm from sinus floor	176	2.65[a]	1.30	407	2.21[a]	1.06	133	2.07[a]	1.05
Lateral wall thickness 13 mm from sinus floor	176	4.59[a]	2.51	40	4.57[b]	2.56	133	3.87[a, b]	2.28
Lateral wall thickness 15 mm from alveolar crest	176	2.94	1.69	407	2.92	1.77	133	2.98	1.85

SD, standard deviation. Within the same row category, values with the same capital letter are statistically different by Tukey's method for post hoc analysis.

36.66 ± 13.51 years) were examined. The lateral sinus wall was measured at the 1st molar region from 3 and 13 mm from the sinus floor, and 15 mm from the alveolar ridge.

Lateral Sinus Wall Thickness

The results of the current study indicate that the lateral sinus wall thickness ranged from 0.30 to 18.9 mm. The mean lateral wall thickness at 3, 13, and 15 mm height were 2.27 ± 1.06, 4.55 ± 2.46, and 2.91 ± 1.76 mm for fe-

males and 2.30 ± 1.19, 4.36 ± 2.55, and 2.96 ± 1.76 mm for males, respectively (Table 1). There was a statistical difference at 13 mm height ($p = 0.001$) between left and right sides. However, there was no statistical difference at 3 mm ($p = 0.078$) and 15 mm ($p = 0.071$).

Age and Gender

There was a statistically significant difference at 3 mm ($p = 0.001$) and 13 mm between the three age groups ($p = 0.015$). However, there was no statistical difference at 15

Table 3. Association between periodontal bone loss and gender and sides

Periodontal bone loss	Male	Female	Right	Left
<25%	165 (23.0%)	150 (20.9%)	145 (20.2%)	170 (23.7%)
25–50%	147 (20.5%)	128 (17.8%)	146 (20.3%)	129 (18.0%)
>50%	86 (12.0%)	42 (5.8%)	68 (9.5%)	60 (8.4%)
p^*	0.012*		0.097	

SD, standard deviation. * $p < 0.05$ presents statistical significance.

Table 4. Association between periodontal bone loss and gender and sides

Periodontal bone loss	Male	Female	Right	Left
<25%	165 (23.0%)	150 (20.9%)	145 (20.2%)	170 (23.7%)
25–50%	147 (20.5%)	128 (17.8%)	146 (20.3%)	129 (18.0%)
>50%	86 (12.0%)	42 (5.8%)	68 (9.5%)	60 (8.4%)
p^*	0.012*		0.097	

SD, standard deviation. * $p < 0.05$ presents statistical significance.

mm for all age groups ($p = 0.989$). Table 2 shows the relation between lateral sinus wall thickness and age. There were no significant differences between gender for lateral wall thickness at 3 mm ($p = 0.736$), 13 mm ($p = 0.334$), and 15 mm ($p = 0.739$) (Table 1).

Periodontal Bone Loss

Mild PBL was observed in 165 (23.0%) male and 150 (20. 9%) female patients. Moderate PBL was noted in 147 (20.5%) male and 128 (17.8%) female patients. Severe PBL was found in 86 (12.0%) male and 42 (5.8%) female patients (Table 3). There were significant associations between PBL and gender ($p = 0.012$), and PBL and age ($p = 0.001$). Table 4 shows the association between PBL and lateral sinus wall thickness. When evaluating the relationship between PBL and lateral sinus wall thickness, the Pearson correlation was used for 3, 13, and 15 mm (Table 4). Negative correlation was identified in 3 mm ($p = 0.001$), 13 mm ($p = 0.042$), and 15 mm ($p = 0.016$).

Discussion

Sinus floor elevation may be required for the placement of implants. However, anatomical differences related with the maxillary sinus have been noticed to increase the incidence of Schneiderian membrane perforation [24]. In surgical procedures, the increased lateral sinus wall thickness is accepted as an important factor for surgical procedures [25]. When lateral sinus wall thickness increases, surgery becomes more difficult and longer. Before surgery, evaluating the thickness of the lateral sinus wall may help the surgeon select correct locations to prevent surgical complications such as membrane perforation [25, 26].

During surgery, to lift the sinus, the inferior horizontal bone osteotomy is performed almost 3 mm above the alveolar crest, and the vertical osteotomies are made 10–15 mm long. Sufficient cavities can be created to accommodate the grafts with adequate maxillary lateral wall. If the aim is to insert the implant in the 13–15 mm in length, superior osteotomy must be performed almost 15 mm above the alveolar ridge, and inferior osteotomy must be performed around 2–3 mm above the floor of the sinus [23, 27]. If the implant is to be placed at a distance of 13 mm, superior osteotomy of the window should be performed 15 mm above the alveolar ridge. The evaluation of maxillary sinus anatomy is imperative to successfully perform sinus-lifting surgery and to avoid surgical and postsurgical complications. However, a few studies have measured maxillary sinus lateral wall thickness [7, 8, 28]. The present study was performed in a large group of dentate patients to detect maxillary sinus lateral wall thickness by using CBCT images to measure with a standardized set of reference points.

No significant differences were found between measurements of mean lateral sinus wall thickness at different reference points in the present research. Further, there was no statistical difference between sexes. The results of this study support previous reports [29, 30] that the anatomy of maxillary sinus in males and females were not found to be significantly different. In their CBCT study, Monje et al. [8] showed that the mean lateral wall thickness was similar in males and females. Contrary to our results, Yang et al. [7] suggested that lateral wall thickness was thinner in females than in males. Kang et al. [23] reported that females had a thinner mean lateral wall thickness at the vertical level of their measurements corresponding to 3 mm from the sinus floor, not 13 or 15 mm. This difference may be related to the measurement made from different reference points and the measurement methods used among the studies. However, there was a statistical difference at 3 and

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13 mm between the three age groups ($p < 0.05$). This is in agreement with a recent study where Monje et al. [8] demonstrated that age influences lateral wall thickness. Kang et al. [23] observed that there was a significant correlation between age and lateral wall thickness at the vertical level measurement of 13 mm from the sinus floor. In contrast to the present study, previous research studies reported no significant differences between lateral wall thickness and participants' ages [1, 7]. In addition, Yang et al. [7] suggested that lateral wall thickness did not vary with age; there was no evidence that older patients had a thinner lateral wall thickness. With age, most people presented with odontogenic problems, such as missing teeth, periodontal disease, abscess, and other pathologic conditions, and these may cause to increase the possibility of maxillary sinusitis [31, 32]. The maxillary sinus of older people may be exposed to irritation during the lifetime, with a decrease in the thickness of the lateral wall.

The results of the present study further demonstrated a statistically significant difference at 13 mm height between the left and right sinus regions ($p < 0.05$). The present results were in agreement with Danesh-Sani et al. [4] who showed a significant difference between the left and right sides of the maxillary sinus. On the other hand, Yang et al. [7] found no significant difference between the left and right sides. Clearly, further studies on maxillary lateral wall thickness are needed. Neighboring anatomic structures (maxillary tuberosity, canine eminence, or zygomatic buttress) influence the topography of the maxillary sinus, hence maxillary sinus lateral bone wall thickness may vary [1].

It is important to clarify if bone loss is caused by the extraction or senility. Two major factors in bone destruction are important; the first one is related to basal bone resorption owing to the increase of the osteoclastic activity of the sinus membrane, and the second one is associated with alveolar bone loss because of the resorption of the marginal bone [23]. The present study was performed in dentate patients due to the presence of periodontal disease. The increased rate of pathogenic bacteria, and their products and inflammatory cytokines around the roots, may directly leak through the maxillary jaw bone or indirectly infiltrate with various blood and lymph vessels. Chronic inflammatory diseases may influence sinus lateral bone wall thickness [33]. Kim et al. suggested that rhinosinusitis and osteitis were crucial factors for bone hyperostosis [21].

The current study identified a negative correlation in the 3 mm ($p = 0.001$), 13 mm ($p = 0.042$), and 15 mm distance ($p = 0.016$) between PBL and lateral sinus wall thickness. Similar to the present findings, Wu et al. [34] found an inverse relationship between alveolar crest height and sinus lateral wall thickness. Further investigations between inflammation and maxillary sinus lateral wall thickness ought to clarify this association. McGowan [35] reported that alveolar bone resorption in an older edentulous maxilla may cause thin cortical bone35]. Yang et al. [1] suggested that periodontal diseases do not have any effects on the lateral wall thickness of the maxillary sinus. However, the present study detected significant associations between PBL and age ($p < 0.001$), and gender ($p < 0.05$). According to the findings of the study, it may be suggested that PBL is an important factor for lateral wall thickness. It is therefore important to be able to predict possible sinus membrane perforation prior to lateral sinus lifting.

The limitations of the present study are the absence of clinical data regarding any previous history of sinusitis and the fact that the study did not limit CBCT to a particular season; scanning was performed in all seasons. Other inflammation related with sinusitis and seasonal differences may affect lateral wall thickness.

Conclusions

It may be suggested that there is an association between PBL and lateral wall thickness. CBCT may provide accurate diagnostic information for better evaluation of the maxillary sinus. Profound knowledge of the sinus and anatomy of the surrounding structures will certainly decrease the risk of complications.

Statement of Ethics

The present retrospective study was approved by the Institutional Review Board.

Disclosure Statement

The authors have nothing to disclose.

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