Age-Related Alteration in the Lateral Wall Thickness of the Maxillary Sinus in Partially or Completely Edentulous Posterior Maxilla: A Cone-Beam Computed Tomography Study

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Abstract

Introduction: Osteotomy of the lateral wall in the lateral window approach for sinus floor elevation carries the risk of perforating the Schneiderian membrane. In this regard, this study aims to evaluate the relationship between age and lateral wall thickness (LWT) of the maxillary sinuses in patients with posterior edentulism. Materials and Methods: A total of 311 cone beam computed tomography (CBCT) scans are analyzed. To measure the lateral sinus, the deepest point in the maxillary sinus floor is selected, a tangent line is drawn to this point, and another line is drawn perpendicular to the previous line. On the latter line, three points are marked at 3, 7, and 10 mm distance from the sinus floor and three lines are drawn passing through these points parallel to the tangent line. The thickness of the lateral sinus wall is measured on these lines. LWT of males and females is compared in different age groups and patients with complete or partial edentulism. The collected data are analyzed using the one-way ANOVA, Scheffe’s test, t-test, and Pearson’s correlation coefficient. Results: There is a significant relationship between age and LWT of the maxillary sinuses. It is so that the LWT decreases as the age increases ($P < 0.001$). Also, the wall thickness of patients with complete and partial edentulism is significantly different ($P < 0.05$). There is no significant difference regarding gender ($P > 0.05$). Conclusion: Age and edentulism type affect the LWT of the maxillary sinuses.

Keywords: Edentulous, lateral wall approach, maxillary sinus

INTRODUCTION

Implant-supported prostheses have become a standard method for reconstructing dentition in patients with partial or complete edentulism.1 However, rehabilitation of edentulous posterior maxilla is a challenging operation that can be complicated with the presence of low-quality alveolar bone with reduced height.2 Elevation of maxillary sinus floor by either a transalveolar or lateral window technique is a well-documented procedure that is broadly used to gain adequate bone height for implant placement.3-5 The lateral window approach is shown to be more predictable than the transalveolar method regarding the outcomes, particularly in cases with minimal bone height.6 Nevertheless, complications are still common. The most widespread complication is the perforation of Schneiderian membrane that occurs in 19.5% of the cases,7 which is directly related to sinus shape/configuration and presence of septum.8 Knowledge of the sinus anatomy, including lateral wall thickness (LWT), is critical to minimize these possible complications.6

Cone beam computed tomography (CBCT) is a widely used technology that provides detailed information regarding the anatomical characteristics of the sinus wall9,10 facilitates diagnosis, and enhances treatment planning.10 In implant dentistry, CBCT helps trace the proper location for implant placement.
placement, estimate bone quality and quantity, and determine the length and diameter of implants.\textsuperscript{[11]} Although the radiographic estimation of the LWT of the maxillary sinus is of great significance in the treatment of dental implants in the posterior maxilla, few studies have investigated this subject.\textsuperscript{[12]}

Despite several studies on sinus augmentation procedures and the rate of complications, research on its characteristics is scarce. Thus, this study aimed to investigate the relationship between age and LWT of maxillary sinuses in patients with posterior edentulism.

**MATERIALS AND METHODS**

A retrospective clinical database that included patients treated as part of routine periodontal care has been used in this study. It is noteworthy that the present data do not comprise any recognizable private information. This study is approved by ethical committee of Qazvin University of Medical Sciences with ethical number of IR.QUMS.REC.1394.603.

**Sample selection**

Overall, 311 measures of CBCT scans of patients fulfilling the inclusion criteria, which will be described in the following section, were taken (81 males and 230 females) (3:1 female to male ratio). The sample size was calculated according to previous studies.\textsuperscript{[6,13]}

Sample group was selected via convenience sampling method. Then, they were categorized into age groups.

**Image acquisition**

The scans used in this study were selected from the CBCT archive database. All images were acquired with a CBCT unit (Planmeca Oy, Helsinki, Finland) in the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Qazvin University of Medical Sciences, Iran, by a qualified radiologist\textsuperscript{1} between 2016 and 2017. The imaging parameters were established at 120 kVp, 18.66 mAs, scanning time of 20s, resolution of 0.4 mm, and field of view that differed based on the scanned area. The CBCT scans of each individual were transported to a desktop computer supplied with implant planning software (InvivoDent, Anatomage, San Jose, CA.). Data were saved in the digital imaging and communications in medicine (DICOM) format.

**Inclusion and exclusion criteria**

An inspector performed image screening using the following inclusion/exclusion criteria.\textsuperscript{[6]}

Images were included if: 1) maxillary sinuses were positioned between premolars and molars due to single or multiple missing teeth; 2) teeth were present adjacent to or opposing the edentulous area so that the location of the edentulous ridges equivalent to the tooth site can be identified; and 3) the maxillary sinus was observable from its floor to 20 mm from the alveolar crest of the edentulous ridge.

Images were excluded if: 1) CBCT scans were of poor quality due to scattering or other reasons; 2) the location of the edentulous ridge could not be verified; 3) the outline of the edentulous ridge could not be distinguished, for example, extraction sockets; or 4) the sinus had been grafted, or implants had been placed.

**Image analysis**

On cross-sectional scans, the area between the canine to second molar teeth was evaluated regarding the LWT of the maxillary sinus. Measurements were done at four sites corresponding to the location of teeth (first and second premolars and first and second molars). In each area, the deepest point of the maxillary sinus floor was chosen, and a line was drawn tangent to this point. At this point, another line was drawn perpendicular to the tangent line. Three points were marked on the perpendicular line at 3, 7, and 10 mm distances from the sinus floor. Then, three lines were drawn passing these points parallel to the tangent line. Finally, the thickness of the lateral sinus wall was measured on these lines [Figure 1]. The reason for choosing these three points is that according to Young’s study, these measurements were performed at 3, 10, and 15 mm intervals in the Korean population. We considered a 7 mm gap between case 1 (i.e. 3 mm) and case 2 (i.e. 10 mm) and wanted to know if there was any difference between Koreans and Iranians.

**Statistical analysis**

The cortical thickness of the lateral wall measured on CBCT scans was reported independently based on gender, age, and type of edentulism (partial or complete). Kolmogorov–Smirnov test was used to assess the normal distribution of data, and a two-sample t-test was performed to compare the LWT with age and gender.

![Figure 1: Measuring the thickness of the lateral sinus wall](image-url)
distribution of data. Cortical bone thickness in different age groups was analyzed using one-way ANOVA followed by post hoc Scheffe’s test. Independent t-test was employed for comparisons between males and females. The relationship between cortical bone thickness and age was analyzed using Pearson’s correlation coefficient. Level of significance was set at 0.05. All statistical analyses were carried out via SPSS version 20 (SPSS Inc., Chicago, IL, USA).

**RESULTS**

A total of 311 CBCT scans were evaluated, out of which 230 (74.0%) belonged to females and 81 (26.0%) belonged to males. The frequency of patients in different age groups is shown in Table 1. As can be seen, 31- to 40-year-old participants had a significantly higher thickness of the lateral wall in the right.

The results of Kolmogorov–Smirnov test showed that the values of LWT on the left side ($P = 0.082$) and the mean values for both right and left sides ($P = 0.088$) had normal distribution, whereas the values of LWT on the left side ($P = 0.007$) were not normally distributed.

The mean and standard deviations (SD) of the LWT of the maxillary sinus in the right side, left side are presented in Table 2. One-way ANOVA showed that the mean thickness of both sides of various age groups are presented in Table 3. One-way ANOVA showed that the LWT in the right and left sides and the mean thickness of both sides of age groups were significantly different ($P < 0.001$). Also, Scheffe’s post hoc test showed that 26–30 and 31– to 41-year-old participants had a significantly higher thickness of the lateral wall in the right ($P < 0.001$) and left sides ($P < 0.001$) in comparison to 41–50 and >51-year-old age groups [Table 4].

Independent t-test showed that there is no significant difference between male and female patients regarding the thickness of the lateral wall [$P > 0.05$, Table 5].

The mean and SD of LWT based on the type of edentulism (partial or complete) are presented in Table 6. Independent t-test showed that there is a significant difference between sinus wall thickness of the right ($P = 0.018$) and left sides ($P < 0.001$) and total mean thickness ($P = 0.009$) of partially edentulous and completely edentulous patients.

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**Table 1: The number and percentage of patients in various age groups**

| Age (years) | Number | Percentage |
|-------------|--------|------------|
| 15–25       | 25     | 8.0        |
| 26–30       | 41     | 13.2       |
| 31–40       | 113    | 36.3       |
| 41–50       | 99     | 31.8       |
| 51 and higher | 33   | 1.6        |

**Table 2: The mean and standard deviations of the LWT of the maxillary sinus in the right or left side**

| Thickness     | Mean | SD  | Minimum | Maximum | F   | P-value |
|---------------|------|-----|---------|---------|-----|---------|
| Right side    | 1.64 | 0.47| 0.60    | 2.93    |     |         |
| Left side     | 1.63 | 0.44| 0.33    | 2.80    |     |         |
| Mean total    | 1.64 | 0.44| 0.63    | 2.70    |     |         |

SD: Standard deviation

**Table 3: Comparison of the mean LWT between the right and the left sides among various age groups and the mean of men and women’s lateral thickness in total**

| Variable                  | Age (years) | Mean | SD  | Minimum | Maximum | F   | P-value |
|---------------------------|-------------|------|-----|---------|---------|-----|---------|
| LWT of the right maxillary sinus | 15–25       | 1.57 | 0.40| 1.13    | 2.30    | 17.32 | <0.001  |
|                           | 26–30       | 1.89 | 0.50| 1.20    | 2.93    |       |         |
|                           | 31–40       | 1.83 | 0.49| 0.60    | 2.87    |       |         |
|                           | 41–50       | 1.41 | 0.29| 0.60    | 2.37    |       |         |
|                           | 51 and older | 1.34 | 0.36| 0.87    | 2.37    |       |         |
| LWT of the left maxillary sinus | 15–25       | 1.55 | 0.40| 1.17    | 2.43    | 19.51 | <0.001  |
|                           | 26–30       | 1.82 | 0.44| 1.10    | 2.80    |       |         |
|                           | 31–40       | 1.84 | 0.42| 0.63    | 2.73    |       |         |
|                           | 41–50       | 1.45 | 0.32| 0.83    | 2.50    |       |         |
|                           | 51 and older | 1.23 | 0.36| 0.33    | 1.97    |       |         |
| Mean value of LWT of the left and right sinuses | 15–25       | 1.58 | 0.42| 1.17    | 2.27    | 14.35 | <0.001  |
|                           | 26–30       | 1.86 | 0.44| 1.15    | 2.70    |       |         |
|                           | 31–40       | 1.83 | 0.44| 0.63    | 2.63    |       |         |
|                           | 41–50       | 1.43 | 0.27| 0.72    | 2.07    |       |         |
|                           | 51 and older | 1.30 | 0.34| 0.82    | 2.17    |       |         |
Table 4: Pairwise comparisons of different age groups regarding the LWT of the maxillary sinuses in the right side, the left side, and the mean of men and women’s lateral wall thickness in total

| Variable                      | Age (years) | Mean difference | P-value |
|-------------------------------|-------------|-----------------|---------|
| LWT of the right maxillary sinus | 15–25       | 26–30           | −0.31   | 0.118             |
|                               | 31–40       | 41–50           | 0.15    | 0.666             |
|                               | 51 and higher | 0.23           | 0.488   |                   |
|                               | 51–60       | 0.23            | 0.488   |                   |
|                               | 61–75       | 0.26            | 0.56    |                   |
|                               | 76+         | 0.30            | 0.66    |                   |
| LWT of the left maxillary sinus | 15–25       | 26–30           | −0.26   | 0.260             |
|                               | 31–40       | 41–50           | 0.14    | 0.931             |
|                               | 51 and higher | 0.31           | 0.142   |                   |
|                               | 51–60       | 0.36            | 0.001   |                   |
|                               | 61–75       | 0.58            | 0.001   |                   |
|                               | 76+         | 0.60            | 0.001   |                   |
| Mean value of LWT of the left and right sinuses | 15–25       | 26–30           | −0.28   | 0.329             |
|                               | 31–40       | 41–50           | 0.14    | 0.815             |
|                               | 51 and higher | 0.27           | 0.373   |                   |
|                               | 51–60       | 0.39            | 0.001   |                   |
|                               | 61–75       | 0.56            | <0.001  |                   |
|                               | 76+         | 0.60            | <0.001  |                   |

Table 5: Comparison of the mean LWT in the right and left sides and the mean of men and women’s lateral thickness in total based on gender

| Variable                      | Sex     | Mean | SD  | Minimum | Maximum | t     | P-value |
|-------------------------------|---------|------|-----|---------|---------|-------|---------|
| LWT of the right maxillary sinus | Male    | 1.59 | 0.45| 0.60    | 2.87    | 1.01  | 0.309   |
|                               | Female  | 1.65 | 0.47| 0.63    | 2.93    |       |         |
| LWT of the left maxillary sinus | Male    | 1.60 | 0.44| 0.57    | 2.60    | 0.57  | 0.563   |
|                               | Female  | 1.64 | 0.45| 2.80    | 0.33    |       |         |
| Mean value of LWT of the left and right sinuses | Male    | 1.60 | 0.44| 0.72    | 2.60    | 0.68  | 0.495   |
|                               | Female  | 1.65 | 0.44| 2.70    | 0.63    |       |         |

Table 6: The comparison of the mean LWT in the right and left sides and the mean of men and women’s lateral thickness in total between partially edentulous and completely edentulous patients

| Lateral sinus wall | Type of edentulism | Number | Mean  | Standard deviation |
|--------------------|--------------------|--------|-------|--------------------|
|                    | Partial            | 236    | 1.667 | 0.441              |
|                    | Complete           | 23     | 1.430 | 0.606              |
|                    | Partial            | 210    | 1.674 | 0.433              |
|                    | Complete           | 29     | 1.341 | 0.452              |
| Total              | Partial            | 166    | 1.675 | 0.413              |
|                    | Complete           | 22     | 1.417 | 0.541              |

P-value = 0.05.
DISCUSSION

In SFE using the lateral window approach, management of the lateral wall is of particular importance in preventing the perforation of the Schneiderian membrane and avoiding subsequent complications. Knowledge about the thickness of the lateral wall is exclusively essential to preserve the integrity of the Schneiderian membrane. An intact Schneiderian membrane, which is approximately 1 mm in thickness, plays a key role in containing the inserted bone graft. It should be kept intact to avoid the loss of graft material and to provide coverage for vascular function. The importance of evaluating the maxillary sinus LWT is to avoid complications during surgery.

It is, therefore, critical to predict possible sinus membrane perforations before the operation. Further, it is important to accurately determine the thickness of the lateral sinus wall and to make a lateral wall osteotomy to open a window to the maxillary sinus.

In the present study, LWT of maxillary sinus in edentulous posterior maxilla was evaluated in patients with complete and partial edentulism. This study was carried out studying CBCT scans of selected Iranian patients because various studies have shown that measurements obtained from CBCT images are comparable to direct cadaveric measurements. The reason for using CBCT scans is ethical, economic, and technical considerations.

The results showed that both age and the type of edentulism (partial or complete) had a significant correlation with the LWT in the right and left sides. The results also showed that 26–30 and 31 to 41-year-old age groups had a significantly higher thickness of the lateral wall in the right (P < 0.001) and left sides (P < 0.001) and mean value of LWT (P < 0.001) in comparison to 41–50 and >51 age groups [Table 4].

The thickness of the lateral wall significantly decreased as the age increased. This finding is in line with the results of the study by Monje et al. [6], who showed the significant effect of age and type of edentulism on the LWT. Khajehahmadi et al. [15] also reported the significant impact of edentulism on the LWT of the maxillary sinus.

Increase in age results in the pneumatization of the maxillary sinus. Accordingly, younger individuals have thicker maxillary sinus lateral wall compared to old ones [3]. This is in contrast to the findings of Kiakojori et al. [16], who stated that there is no relationship between gender and age with the sinus LWT.

In this study, no significant difference was observed in the LWT of the maxillary sinus in terms of gender, which is in accordance with the findings of Monje et al. [6] and Khajehahmadi et al. [15]. Recently, Talo Yildirim et al. [17] reported that there is no significant relationship between LWT and gender. They revealed that the effects of height (from 3 to 15 mm of sinus floor) on LWT are significant. It is such that increasing height results in the increased mean LWT. There was a statistically significant difference at 3 mm and 13 mm heights in three age groups. However, there was no statistical difference at 15 mm height among all age groups.

Neiva et al. [12] reported that the mean LWT in females is significantly smaller than the corresponding value in males (0.75 ± 0.33 mm and 1.18 ± 0.46 mm, respectively). The discrepancy between the results of that study with the current research may be due to the different populations under study, which included the Caucasians with a mean age of 78.2 ± 9.03 years for males and 79.7 ± 13.12 years for females. Also, their method of measurement was different. It should be noted that studies using CBCT have the inherent risk of bias due to the complexity of the device, which may be partly responsible for the variability in the results. [14,18]

The results of this study also revealed that the mean thickness of lateral sinus wall is significantly smaller in patients with complete edentulism compared to partially edentulous patients, which is in line with the findings of Monje et al. [6]. Khajehahmadi et al. [15] also reported reduced thickness of the lateral wall in completely edentulous patients compared to partially edentulous patients, although the difference in their study was not statistically significant. In contrast, Yang et al. [13] reported a higher mean thickness in completely edentulous patients compared to partially edentulous patients. This difference in the results of studies may be attributed to the reference landmarks used for measurements or ethnic group of patients. [9] For instance, the mean LWT measured on the skulls of Caucasians by Neiva et al. [12] was smaller than the value observed in the current study, which may be due to racial issues or internal bias because of CBCT device distortion, the device or software used for measurements. Neiva et al. [12] argued that thicker lateral walls in young patients might probably be due to less pneumatization of the maxillary sinuses. However, further studies are required to elucidate this subject better. Furthermore, adjacent structures such as the supporting zygomatic bone, canine eminence, and maxillary tuberosity may affect the topography of the maxillary sinus, and therefore, the thickness of the lateral wall of the maxillary sinuses. [14,19,20]

Future studies are recommended to assess the radiographic correlation between age and gender with the dimensions of the ridge base and the LWT of the maxillary sinus.

Some of the limitations of this study are the use of three-dimensional imaging technique that is less cost-effective and is increasingly exposed to radiation. Another limitation of this study is the greater number of female samples in comparison to male samples. The other problem encountered in this study was the problems associated with imaging, including software or distortion.

CONCLUSION

The results showed that age had a significant negative correlation with the LWT of the maxillary sinus in the
selected Iranian population. Also, it was found that completely edentulous patients had a smaller thickness of lateral wall compared to partially edentulous subjects, which might be different in other populations.

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Conflicts of interest
There are no conflicts of interest.

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