Evaluation of the posterior superior alveolar artery and the maxillary sinus with CBCT

Abstract: Assessment of the maxillary sinus anatomy before sinus augmentation is important for avoiding surgical complications, because of the close anatomical relationship between the posterior maxillary teeth and the maxillary sinus. The posterior superior alveolar artery (PSAA) is the branch of the maxillary artery that supplies the lateral sinus wall and overlying membrane. We evaluated the location of the PSAA and its relationship to the alveolar ridge and maxillary sinus using cone beam computed tomography (CBCT). The study group consisted of 135 CBCT scans (270 sinuses) obtained from the archive of the dentomaxillofacial radiology department at Yeditepe University Faculty of Dentistry, Istanbul, Turkey. The distance between the lower border of the artery and the alveolar crest, bone height from the sinus floor to the ridge crest, distance from the artery to the medial sinus wall, and the diameter and location of the artery were determined. The occurrence of septa and pathology were recorded from CBCT scans. The PSAA was observed in 89.3% of sinuses, and 71.1% of arteries were intraosseous with diameters mostly ≤1 mm (68.9%). The prevalence of sinus septa was 55.2%, and that of sinus pathology was 57.4%. The mean age was 43.07 ± 17.55 years. There was a statistically significant difference between the location of the artery and gender (p < 0.05). The prevalence of sinus membrane thickening was 57.4%. Detailed knowledge about the location of the PSAA and sinus morphology may be obtained with CBCT before maxillary sinus surgery.

Descriptors: Maxillary Artery; Maxillary Sinus; Cone-Beam Computed Tomography.

Introduction

The posterior superior alveolar artery (PSAA) and infraorbital artery (IOA) are the branches of the maxillary artery that supply the lateral sinus wall and overlying membrane. The blood supply of the maxillary sinus and Schneiderian membrane comes from the maxillary artery.1,2 Sinus augmentation is a safe procedure with high predictability for rehabilitation of severely atrophic posterior maxillae.3-6 The branches of the maxillary artery should be taken into consideration during sinus augmentation because of the potential risk of bleeding during the procedure owing to damage to the vascular supply in the lateral wall.7 Assessment of the maxillary sinus anatomy is important to avoid unnecessary complications due to the close anatomical relationship of the PSAA with the
Any imaging technique that subjects the patient to ionizing radiation must yield as much pertinent information as possible, and it is important that the physician collect all the useful information possible. Cone beam computed tomography (CBCT) may be recommended as a dose-sparing technique compared with standard medical computed tomography (MDCT) scans for dentomaxillofacial imaging. Increases in kV, mA, exposure time, and field of view increase the radiation dose regardless of the type of imaging technique used. The effective dose (International Commission on Radiological Protection - ICRP 2007) from a standard dental protocol scan with MDCT is 1.5 to 12.3 times greater than from comparable medium-field of view dental CBCT scans. Thus, CBCT is frequently used for preoperative assessment of the alveolar ridge and maxillary sinus in patients receiving implants in the posterior maxilla.

The purpose of this study was to evaluate the location of the PSAA and its relationship to the alveolar ridge and maxillary sinus using CBCT.

**Methodology**

The study design underwent formal review and received approval from the institutional review board of our institution. The retrospective study group was planned according to Sample Size Estimation Simple Random Sampling and consisted of 135 CBCT scans of 55 males and 80 females (270 sinuses) obtained from the archive of the Dentomaxillofacial Radiology Department of the faculty. Patient ages ranged from 18 to 83 years. Digital images were taken using an Iluma CBCT scanner (Intec Corporation, Oberursel, Germany) with an amorphous silicon flat-panel image detector and a cylindrical volume of reconstruction of up to 19 × 24 cm. Images were taken at 120 kVp, 3.8 mA, and a voxel size of 0.2 mm, with an exposure time of 40 seconds. 3D reconstructions were created by reformatting the axial CBCT scans on a local workstation using Iluma dental imaging software (Intec Corporation). A written informed consent form, which is routinely obtained from each patient prior to imaging in our faculty, also included a clause for the use of images in this research. Before measurements were made, the orientation of the images was determined for each patient.

On coronal scans, evaluation was made between where the artery was first and last seen. The distance between the lower border of the artery and the alveolar crest (A), bone height from the sinus floor to the ridge crest (B), distance from the artery to the medial sinus wall (C), and the diameter and location of the artery were determined (Figure 1); occurrence of sinus septa and membrane thickening were also recorded from CBCT scans. Locations of the artery were:

- a. intraosseous (Figure 2),
- b. below the membrane (Figure 3), and
- c. on the outer cortex of the lateral sinus wall (Figure 4).

A and B were calculated for only the edentulous alveolar crest.

A dentomaxillofacial radiology specialist evaluated the images in a darkened quiet room with dual monitors (HP LP2475W, resolution 1920 × 1200; Hewlett-Packard, Houston, USA). Each viewing ses-
The mean age of the study participants was $43.07 \pm 17.55$ years. The intraclass correlation coefficient results reflect the intra-observer reliability, which is a measure of whether the observer assigned similar ratings with repeated observations for each measurement. Intraclass correlation coefficient

**Results**

The mean age of the study participants was $43.07 \pm 17.55$ years. The intraclass correlation coefficient results reflect the intra-observer reliability, which is a measure of whether the observer assigned similar ratings with repeated observations for each measurement. Intraclass correlation coefficient
scores of measurements A, B, and C were 0.95, 0.98, and 0.97, respectively. Kappa values for the diameter and location of the artery were 81.5% and 98%, respectively, and for the occurrence of septa and pathology they were 86.5% and 93%, respectively.

The PSAA was observed in 89.3% of all sinuses; 71.1% of arteries were intraosseous, 13% were below the membrane, and only 5.2% were on the outer cortex of the lateral sinus wall. The artery diameters ranged from 0.4 to 1.7 mm with a mean value of 0.94 ± 0.26 mm. The artery diameters were mostly ≤1 mm (68.9%). The percentages of artery diameters ≤1 mm were 73.5% and 64.5% for the right and left sinuses, respectively, and there was no statistically significant difference (p > 0.05). More males (39.8%) than females (25.2%; p < 0.05) had an artery diameter of 1 to 2 mm. No significant correlation was found between the presence of the artery and age/gender (p > 0.05). A statistically significant difference was found between locations of the artery and gender (p < 0.05). A statistically significant difference was found between locations of the artery and gender (p < 0.05). A statistically significant difference was found between locations of the artery and age/gender (p > 0.05). A statistically significant difference was found between locations of the artery and gender (p < 0.05). Although the prevalence of an intraosseous PSAA was significantly higher in females (74.4%) than males (66.4%), the PSAA was located on the outer cortex of the lateral sinus wall in males (10%) significantly more often than in females (1.9%; Table 1; p < 0.05).

Regarding the prevalence of the artery, there was a statistically significant difference between edentulous and dentulous alveolar crest where the artery was identified. The artery was observed less often in the edentulous crest (75.9%) than dentulous crest (99.4%; p < 0.01). No statistically significant difference was observed between gender and distance from the artery to the alveolar crest (p > 0.05; Table 2). The distance from the artery to the medial sinus wall in males was significantly higher than in females (p < 0.05). With regard to the edentulous crest, the mean distance from the artery to the alveolar crest was 16.88 ± 3.46 mm (A), and the bone height from the sinus floor to the ridge crest (B) was 7.84 ± 3.20 mm. The mean distance from the artery to the medial sinus wall (C) in dentulous crests (13.92 ± 2.84 mm) was significantly higher than that measured for the edentulous crest (13.00 ± 2.32 mm; p < 0.05). There also was a statistically significant difference among age groups regarding the distance from the artery to the medial sinus wall (p < 0.01; Table 3). According to the Pearson correlation test, a negative (−20.1%) correlation

### Table 1 - Artery localization according to age, gender, and edentulous/dentulous alveolar crest.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Absence</th>
<th>Intraosseous</th>
<th>Below the membrane</th>
<th>On the outer cortex of the lateral sinus wall</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–29</td>
<td>7 (9.0)</td>
<td>55 (70.5)</td>
<td>11 (14.1)</td>
<td>5 (6.4)</td>
<td>0.129</td>
</tr>
<tr>
<td>30–39</td>
<td>1 (2.8)</td>
<td>30 (83.3)</td>
<td>4 (11.1)</td>
<td>1 (2.8)</td>
<td></td>
</tr>
<tr>
<td>40–49</td>
<td>2 (5.9)</td>
<td>29 (85.3)</td>
<td>3 (8.8)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>50–59</td>
<td>13 (17.6)</td>
<td>43 (58.1)</td>
<td>14 (18.9)</td>
<td>4 (5.4)</td>
<td></td>
</tr>
<tr>
<td>≥60</td>
<td>6 (12.5)</td>
<td>35 (72.9)</td>
<td>3 (6.3)</td>
<td>4 (8.3)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Absence</th>
<th>Intraosseous</th>
<th>Below the membrane</th>
<th>On the outer cortex of the lateral sinus wall</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>17 (10.6)</td>
<td>119 (74.4)</td>
<td>21 (13.1)</td>
<td>3 (1.9)</td>
<td>0.03*</td>
</tr>
<tr>
<td>Male</td>
<td>12 (10.9)</td>
<td>73 (66.4)</td>
<td>14 (12.7)</td>
<td>11 (10.0)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Edentulous</th>
<th>Absence</th>
<th>Intraosseous</th>
<th>Below the membrane</th>
<th>On the outer cortex of the lateral sinus wall</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 (24.1)</td>
<td>68 (58.6)</td>
<td>12 (10.3)</td>
<td>8 (6.9)</td>
<td></td>
<td>0.00**</td>
</tr>
<tr>
<td>Dentulous</td>
<td>1 (0.6)</td>
<td>124 (80.5)</td>
<td>23 (14.9)</td>
<td>6 (3.9)</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01 (chi-square test).

### Table 2 - Measurements according to gender.

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A**</td>
<td>16.79 ± 3.79</td>
<td>17.00 ± 2.94</td>
<td>0.785</td>
</tr>
<tr>
<td>B***</td>
<td>7.50 ± 3.03</td>
<td>8.34 ± 3.43</td>
<td>0.233</td>
</tr>
<tr>
<td>C****</td>
<td>13.27 ± 2.82</td>
<td>14.03 ± 2.44</td>
<td>0.031*</td>
</tr>
</tbody>
</table>

*p < 0.05 (Student’s t test). **Distance between the lower border of the artery and the alveolar crest. ***Bone height from the sinus floor to the ridge crest. ****Distance from the artery to the medial sinus wall.
was found between these two parameters ($p < 0.01$). Increased age was negatively associated with the distance between the artery and the medial sinus wall. In other words, older participants tended to have a shorter distance between their artery and the medial sinus wall. The reason may be that the number of arteries were $1\text{ mm}$, $2\text{ mm}$, and $5.5\text{ mm}$, respectively. Similarly, in anatomic studies, the diameter was reported to be $1.6\text{ mm}$ at the exit from the maxillary artery. In our study group, the mean artery diameter was $1.3\text{ mm}$, $1.2\text{ mm}$, and $1.52\text{ mm}$, respectively. Similarly, in anatomic studies, the diameter was reported to be $1.6\text{ mm}$ at the exit from the maxillary artery. 

According to Kim et al.,16 the prevalence of the PSAA differs significantly between males ($64\%$) and females ($40\%$). In the present study, no significant correlation was found between gender and presence of the artery. The reason may be that the number of males/females differs between the two studies.

Table 2 shows that the mean distance of the artery from the alveolar ridge was $16.79\pm 3.79\text{ mm}$ for females and $17.00\pm 2.94\text{ mm}$ for males. In anatomic studies, this distance was reported to be $18.9–19.6\text{ mm}$.1,2 We observed a shorter distance than in these anatomic studies. The differences may be due to the small number of cases evaluated with CT in previous studies as reported by Güncü et al.,13 (18 mm), Elian et al.,14 (16.4 mm), Mardinger et al.,15 (16.9 mm), and Kim et al.16 (18.9 mm). Our current results are close to those of these studies.

In the present study, the mean distance from the artery to the crest was $7.50\pm 3.03\text{ mm}$ in females and $8.34\pm 3.43\text{ mm}$ in males. The mean distance from the artery to the antral floor was $9.29\text{ mm}$ in females and $8.66\text{ mm}$ in males. This distance reported by Güncü et al.,13 was $7.8\pm 0.3\text{ mm}$ and by Mardinger et al.,15 was 7–8 mm. These differences may be explained by the anatomic variation in the positions of arteries.

Damage to the bony vessel can cause bleeding, may obscure the physician’s line of sight, and may lead to perforation of the Schneiderian membrane, all of which prolong the operation and assessment of the sinus membrane reflection.17 According to our current results, the mean artery diameter was $0.94\pm 0.26\text{ mm}$. However, Güncü et al.,13 Ella et al.,7 and Kim et al.16 reported larger diameters of 1.3 mm, 1.2 mm, and 1.52 mm, respectively. Similarly, in anatomic studies, the diameter was reported to be 1.6 mm at the exit from the maxillary artery.1,2

In our study group, artery diameter was generally ≤ 1 mm ($68.9\%$). Güncü et al.,13 reported that only 36.1% of arteries were ≤ 1 mm, Mardinger et al.,15 reported that 26% of sinuses have vessels ≤ 1 mm, and Kim et al.16 detected 13.9% of vessels with diameters < 1 mm. We found that the artery was ≥ 1 mm in 31.1% of patients, which may suggest that the in-

### Discussion

Sinus augmentation is a method with high predictability for placing successful dental implants into atrophic posterior maxillae.3-6 Knowledge of the anatomic structure of the area is important for this procedure. In the present study, we were able to observe the presence and location of the PSAA with CBCT scans. The artery was observed in 89.3% of the sinuses and was mostly intraosseous ($71.1\%$). The success rate for identifying the artery was higher than that reported by Güncü et al.,13 ($64.5\%$), Elian et al.,14 ($52.9\%$), Mardinger et al.,15 ($55\%$), and Kim et al.,16 ($52\%$). This may be related to the methods the other groups used to detect and describe the artery. Collectively, these results suggest that an undetected intrabony canal in a CT scan does not exclude its existence but that it may not be visible owing to its small diameter.15 CBCT provides accurate and reliable linear measurements for reconstruction and imaging of dental and maxillofacial structures.7,9

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### Table 3 - Measurements according to age groups.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–29</td>
<td>A**</td>
<td>17.01 ± 3.01</td>
<td>17.52 ± 4.18</td>
<td>17.05 ± 2.93</td>
<td>15.97 ± 3.42</td>
<td>17.40 ± 3.54</td>
</tr>
<tr>
<td>30–39</td>
<td>B***</td>
<td>8.29 ± 3.20</td>
<td>9.62 ± 3.28</td>
<td>7.74 ± 1.70</td>
<td>7.65 ± 3.76</td>
<td>7.50 ± 2.92</td>
</tr>
<tr>
<td>40–49</td>
<td>C****</td>
<td>14.18 ± 2.48</td>
<td>14.89 ± 2.40</td>
<td>13.00 ± 2.27</td>
<td>12.60 ± 3.05</td>
<td>13.34 ± 2.45</td>
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<tr>
<td>50–59</td>
<td></td>
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<tr>
<td>≥ 60 years</td>
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</table>

*p < 0.01 (one-way analysis of variance). **Distance between the lower border of the artery and the alveolar crest. ***Bone height from the sinus floor to the ridge crest. ****Distance from the artery to the medial sinus wall.
cidence of intense bleeding during a sinus augmentation is low.

In our study group, the average diameter of arteries was higher in males (39.8%) than females (25.2%). Although Güncü et al.13 and Kim et al.16 reported similar results, Mardinger et al.15 found no difference between men and women regarding the diameter of the artery. Anatomic variations in the maxillary sinus may be important for dental implant planning. In some instances, dental implant planning may require modifications related to sinus morphology. Results from our present study revealed that sinus septa were observed in 55.2% of the 270 sinuses. The prevalence of sinus septa found by Güncü et al.13 was 16.1%, by Krennmair et al.18 was 16%, and by Kim et al.19 was 26.5% when CT was used to assess the sinuses. These results are not consistent with those of the present study. On the other hand, much higher percentages have been reported with CBCT, and they are close to the results obtained in our present study. Orhan et al.20 reported that the prevalence of sinus septa was 58%, and Neugebauer et al.21 reported that it was 47%. Lana et al.22 stated that the prevalence of antral septa was 44.4%. The data in these reports may be due to the use of CBCT to identify the septa. Lana et al.22 also found that the prevalence of mucosal thickening was 54.8% (≤ 3 mm) and 62.6% (≥ 3 mm) with CBCT. The prevalence of sinus membrane thickening was 57.4% in our present study. However, we evaluated only the existence of sinus mucosa thickening, and the thickness was not measured. The prevalence of thickening reported by Lana et al.22 was consistent with those of the present study.

Conclusion

We conclude that preoperative imaging with CBCT seems to be helpful for assessing the location of the PSAA and the maxillary sinus morphology, which may be used to adjust the surgical treatment plan to yield more successful dental implant treatments.

References