Evaluation of the location of the posterior superior alveolar artery in the maxillary sinus by Cone beam computed tomography

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ABSTRACT

Background: Considering the growing interest in dental implants to replace missing teeth and the subsequent increase in sinus augmentation surgery, one of the anatomical landmarks that may be injured during this procedure is the posterior superior alveolar artery (PSAA). The purpose of this study was to evaluate the location of PSAA using cone beam computed tomography (CBCT) scans.

Methods: 160 CBCT scans of 80 females and 80 males with age range of 20 to 86 years were selected. The location of PSAA were examined on cross-sectional images from the first premolar to the third molar areas of left and right maxillary sinuses. The distances of artery to sinus floor, alveolar crest and medial wall of the maxillary sinus and the artery diameter were measured. Data were analyzed using SPSS software V.22 and T-Test and ANOVA.

Results: The mean PSAA diameter from the first premolar to the third molar was 0.75, 0.82, 0.92, 0.95 and 1.03 mm, respectively. The closest distances of the artery to alveolar crest were seen in the first and second molars areas with mean 16.11 and 16.65 mm in which, PSAA is close to the maxillary sinus membrane. The distances of artery to sinus floor and alveolar crest and artery diameter were higher in males than females (p<0.001). The distance of the PSAA to the medial wall of the sinus is decreased with increasing age (p=0.015). Left and right sides showed no significant differences.

Conclusion: Due to anatomical variation, evaluation of maxillary sinus using CBCT before sinus augmentation surgery by a surgeon or radiologist can be useful in planning a more precise treatment and avoiding unwanted side effects.

Keywords: Cone beam computed tomography; maxillary sinus; posterior superior alveolar artery; dental implants

INTRODUCTION

The proper quality and quantity of bone for implant placement in the jaws are so important. In the posterior maxillary ridge, it can be affected by ridge atrophy or penomatisation of maxillary sinus (1, 2). The sinus augmentation surgery is a predictable procedure to rehabilitate the posterior maxillary ridge. There are two main methods for vertical sinus augmentation for implants: two-step method through lateral wall of the sinus (lateral window approach), that after the healing period, the implant is embedded; one-step method that is performed either the lateral wall of the sinus or through the alveolar crest (transalveolar approach) (3, 4). This surgery may get problematic due to inner anatomic structures of the maxillary sinus that
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increases the risk of surgical complications and increases the time of surgery. Bone thickness of the sinus floor and lateral wall of sinus may be different. Each sinus may behave one or more septa. Membrane perforations, can also be one of the postoperative complications (5, 6). Bleeding can also cause difficulty in visibility and an unnecessary increase in surgical time and also cause postoperative pain, inflammation and infection (7, 8). Blood supply of Anterolateral wall and Schneiderian membrane of the maxillary sinus is from the Infra-orbital and the posterior superior alveolar artery (PSAA). These arteries are two branches of the maxillary artery. PSAA runs caudally in the lateral wall of the sinus and in close contact with bone and periosteum (9, 10). Examining the sinus anatomy is important to avoid unnecessary problems caused by the proximity of PSAA and Anterolateral wall of maxillary sinus (11, 12). Lateral Osteotomy of maxillary sinus has the potential risk of bleeding during surgery (8). Although the PSAA bleeding is not a risk for an experienced surgeon, but can be troublesome for a less experienced dentist (7). To examine the maxillary sinus, panoramic radiography can cause problem for quantitative measurements and interpretation because of the inherent distortion and the two-dimensional nature of technique (13). CBCT with high resolution images of maxillary sinus with more accurate information and quantitative measurements and lower dose can be used (14-16). CBCT images can provide valuable information including bone morphology, the presence of pathological conditions and anatomical landmark like PSAA (14). Since sinus anatomy is varied in different races and it is necessary to conduct studies in different areas, the aim of this study is to evaluate the location and anatomy of PSAA and its relationship with the alveolar ridge and maxillary sinus using CBCT images in a selected Iranian population.

MATERIALS AND METHODS

160 CBCT scans of patients from the archives of two Oral and Maxillofacial Radiology Centers, during 2015-2016 were selected. All scans were prepared by Newtom5G / Verona / Italy and Cranex3D / Soredex / Helsinki / Finland with NNT viewer and On demand 3D Dental softwares. Scans selection criteria were as follows:

1. The maxillary sinuses should be visible and measurable bilaterally in the scans.
2. The patient should not have any sinus lift or orthognathic surgery.
3. There should not be any destructive pathological lesions of sinus wall which affect the measurement such as a cyst or tumor.

Images were examined using a personal monitor the Lenovo IdeaPadZ5070, 15.6 inch TFT LED-backlit LCD with Full HD 1920x1080 resolution screen. The multiplanar reconstruction was obtained using computer software. PSAA were studied in cross-sectional views of anterolateral wall of the sinus. The trajectory of the artery were divided into ten areas: first premolar areas on right and left sides 14 and 24; second premolar areas on the right and left sides 15 and 25; first molar areas on the right and left sides 16 and 26; second molar areas on the right and left sides 17 and 27; third molars on the right and left sides 18 and 28 respectively. In each area, if any PSAA was observed, the artery diameter would be measured. The location of the artery was recorded in 3 positions: interosseous, close to the membrane and on the outer cortex of lateral sinus wall (Figure 1).

Figure 1. The position of artery towards the lateral sinus wall in the CBCT cross section images. a. close to sinus membrane. b. interosseous. c. on the outer cortex.
Two parallel lines were drawn horizontally from the most coronal surface of buccal crest and sinus floor that were considered as the alveolar crest and sinus floor surfaces, respectively. The distances of the PSAA to the alveolar crest surface, sinus floor, and medial wall of the sinus and distance of the sinus floor to the crest surface were measured (Figure 2). All measurements were done by one observer using the software tool. After two months, 10% of the samples were re-evaluated by the observer. Data were analyzed using SPSS software V. 22 (SPSS Inc., Chicago, IL, USA) and t-test and ANOVA tests. A P-value of less than 0.05 was considered statistically significant.

**RESULTS**

In this study, 320 scans of right and left maxillary sinus of 160 patients (80 males, 80 females) with an age range of 20-86 years with a mean age of 45.15±14.61 were evaluated. The PSAA was detected in 129 right maxillary sinus (80.63%), and also in 130 left maxillary sinus (81.25%), in at least one of the five dental areas. Most of undetected arteries were in the first premolars, and most detected ones were observed in the first and second molars. In the first and second molar areas, artery was mostly close to the membrane of the maxillary sinus, while in the premolar area it was mostly seen in intraosseous position. Most presence of artery on the outer cortex of the maxillary sinus walls was detected at third molars areas (Figure 3).

**Figure 2** The measurements in CBCT Cross-sectional images. a, artery diameter. b, distance of the artery to the alveolar crest surface. c, distance of the artery to sinus floor. d, distance of the artery to the medial wall of the sinus.

**Figure 3** Prevalence and location of PSAA according to dental areas in percentage (4 first premolar, 5 second premolar, 6 first molar, 7 second molar, 8 third molar).
The mean diameter of PSAA was 0.91±0.31 mm, in range of 0.4-2.2 that in 69.81% it was ≤1 mm. The diameter was ≥2 mm was seen in 0.7%, and 1-2mm in 29.49%. PSAA diameter from the first premolars to third molar in both left and right sides showed increase (Table 1), which was statistically significant (p<0.001). Artery diameter was significantly higher (p<0.001) in men 1.02±0.32 (0.4-2.2) mm than women 0.82±0.25 (0.4-2) mm (Table 2).

**Table 1.** The mean and SD of PSAA diameter and the PSAA distances to the alveolar crest, sinus floor, and medial wall of the sinus, and the distance from the alveolar crest to sinus floor divided by dental areas in mm

<table>
<thead>
<tr>
<th></th>
<th>First premolar</th>
<th>Second premolar</th>
<th>First molar</th>
<th>Second molar</th>
<th>Third molar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PSAA diameter</strong></td>
<td>0.75±0.27</td>
<td>0.82±0.24</td>
<td>0.92±0.27</td>
<td>0.95±0.31</td>
<td>1.03±0.36</td>
</tr>
<tr>
<td><strong>PSAA distance to the alveolar crest</strong></td>
<td>22.63±3.92</td>
<td>19.3±3.88</td>
<td>16.11±3.55</td>
<td>16.65±3.31</td>
<td>19.2±2.85</td>
</tr>
<tr>
<td><strong>PSAA distance to sinus floor</strong></td>
<td>5.64±4.54</td>
<td>5.99±3.84</td>
<td>6.88±3.55</td>
<td>8.06±3.78</td>
<td>9.75±3.73</td>
</tr>
<tr>
<td><strong>PSAA distance to the medial wall of the sinus</strong></td>
<td>4.3±2.14</td>
<td>6.82±3</td>
<td>11.77±3.4</td>
<td>13.51±2.7</td>
<td>13.32±2.34</td>
</tr>
<tr>
<td><strong>Crest distance to sinus floor</strong></td>
<td>17.11±5</td>
<td>13.31±4.7</td>
<td>9.21±3.92</td>
<td>8.64±3.7</td>
<td>9.55±3.7</td>
</tr>
</tbody>
</table>

**Table 2.** The mean and SD of the artery diameter and the artery distances to the alveolar crest and sinus floor, divided by gender in mm

<table>
<thead>
<tr>
<th></th>
<th>First premolar</th>
<th>Second premolar</th>
<th>First molar</th>
<th>Second molar</th>
<th>Third molar</th>
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</thead>
<tbody>
<tr>
<td><strong>Artery diameter</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.65±0.19</td>
<td>0.77±0.19</td>
<td>0.84±0.25</td>
<td>0.85±0.26</td>
<td>0.9±0.31</td>
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<tr>
<td>Male</td>
<td>0.88±0.3</td>
<td>0.89±0.29</td>
<td>1±0.27</td>
<td>1.06±0.31</td>
<td>1.15±0.37</td>
</tr>
<tr>
<td>t-test</td>
<td>P&lt;0.001</td>
<td>P=0.001</td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td><strong>Artery distance to alveolar crest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>21.9±3.55</td>
<td>18.81±3.8</td>
<td>15.82±3.42</td>
<td>16±3.2</td>
<td>18.25±2.68</td>
</tr>
<tr>
<td>Male</td>
<td>23.6±4.2</td>
<td>19.94±3.92</td>
<td>16.42±3.68</td>
<td>17.34±3.3</td>
<td>20.16±2.72</td>
</tr>
<tr>
<td>t-test</td>
<td>P=0.04</td>
<td>P=0.04</td>
<td>P=0.19</td>
<td>P=0.002</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td><strong>Artery distance to sinus floor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>5.03±3.98</td>
<td>5.06±3.19</td>
<td>6.35±3.21</td>
<td>6.95±3.01</td>
<td>8.55±3</td>
</tr>
<tr>
<td>Male</td>
<td>6.44±5.12</td>
<td>7.21±4.4</td>
<td>7.54±3.82</td>
<td>9.23±4.15</td>
<td>10.95±4</td>
</tr>
<tr>
<td>t-test</td>
<td>P=0.15</td>
<td>P&lt;0.001</td>
<td>P=0.017</td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
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</table>

No significant difference was observed between the right and left sides and in age groups. In comparison of dentulous subjects and tooth extraction cases, according to the edentulous period, no significant relationship was observed in terms of the diameter of the artery. PSAA distance to the medial wall of maxillary sinus is presented in Table 1 in which this distance was increasing from the first premolars to second molars and this increase was statistically significant (p<0.001). There was no significant relationship between men and women, right and left sides, and tooth extraction history. With age, the pattern of the decreased distance of artery to medial wall of the maxillary sinus was observed which was significant in the first premolar, first and second molars areas (Table 3).
Table 3. The distance of artery to the medial wall of the maxillary sinus divided by age groups in mm

<table>
<thead>
<tr>
<th>Age</th>
<th>First premolar</th>
<th>Second premolar</th>
<th>First molar</th>
<th>Second molar</th>
<th>Third molar</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-40</td>
<td>5.05±2.2</td>
<td>7.45±2.78</td>
<td>12.85±3.12</td>
<td>14.11±2.41</td>
<td>13.47±2.41</td>
</tr>
<tr>
<td>41-60</td>
<td>3.64±2.07</td>
<td>6.5±3.23</td>
<td>11.41±3.3</td>
<td>13.28±2.81</td>
<td>13.21±2.17</td>
</tr>
<tr>
<td>Above 60</td>
<td>4.2±1.04</td>
<td>6.2±2.5</td>
<td>10.53±3.91</td>
<td>12.69±2.77</td>
<td>12.45±3.22</td>
</tr>
<tr>
<td>P-value</td>
<td>0.11</td>
<td>0.62</td>
<td>0.001</td>
<td>0.017</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The distance of PSAA to alveolar crest and distance of PSAA to the maxillary sinus floor and the distance of the alveolar crest to the maxillary sinus floor are shown from the first premolar to third molar in Table 1. The distance of PSAA to the maxillary sinus floor was increased from anterior to the posterior and this trend was significant (p<0.001). The distance of PSAA to sinus floor in men 8.46±4.44(0-22.43) mm was more than women 6.44±3.42 (0-15.69) mm (Table 2) and it was significant (p<0.001). This distance was not correlated with age. The least distance of artery to alveolar crest surface and the least height of alveolar ridge were found in the first and second molars. The mean distance of the PSAA to the alveolar crest was 18.13± 4.03(6.6-31.74) mm, which was 18.72±4.12 in the men more than women 17.61±3.88 mm (Table 2) that was significant in the first and second premolars, and second and third molars areas. The distance of alveolar crest to the maxillary sinus floor had a downward trend from the first premolar to the second molar that was significant (p<0.001). In comparison of dentulous subjects and tooth extraction cases with over 5 years history, the mean distance of artery to crest was 18.35±4.02 mm compare 17.46±3.95 (p = 0.002); and the alveolar crest to the maxillary sinus floor was decreased from 11.7±4.78 to 8.95±4.53 mm (p<0.001) and distance of artery to sinus floor was increased from 6.73±3.61 to 8.5±4.49 mm (p<0.001).

Comparison of the distance of the PSAA to the alveolar crest surface, distance of the PSAA to sinus floor and distance of the sinus floor to the crest surface divided by dentulous subjects and tooth extraction for over 5 years history are presented in the Figures 4 and 5. There was a significant differences in distance of the PSAA to the alveolar crest surface with tooth loss at second premolar and first molar areas (p= 0.003, p= 0.001). There was also a significant relationship between distance of PSAA to sinus floor and tooth loss history at second premolar and second molar areas (p = 0.010, p<0.001). Similarly, there was a significant relationship between distance of the sinus floor to the crest surface and tooth loss history at second premolar, first molar and second molar areas (p<0.001).
DISCUSSION
In this study, each maxillary sinus evaluated in the 5 dental positions. From total of 320 right and left maxillary sinus, PSAA was detected at least one dental position in 259 cases (80.94%). The reported PSAA detection rates in previous studies of Güncü et al. (17) 64.5%, Mardinger et al. (18) 55%, Kim et al. (19) 52%, Elian et al. (20) 52.9% were lower than this study that may be due to the use of CT in those studies. More recent studies, in which using CBCT, this rate was higher as in the studies of Nicolielo et al. (21) 73.5% in the Brazilian population, (22) Khojastepour et al. 80.6% in the Iranian population, (23) Apostolakis et al. 82% in the Greek population, and (24) Ilgüy et al. 89.3% in the Turkish population which were close to the results of this study. The detected arteries in this study was mostly seen in the first and second molars and close to maxillary sinus membrane that was the same as Nicolielo et al. study (21). In studies of Güncü et al. (17) and Ilgüy et al. (24) the artery was observed mostly intraosseous 68.2% and 71.1%, but in the study of Khojastepour et al. (22) the artery was seen close to membrane 49.8%. In the present study, the artery in 49.7% of cases was detected close to membrane, 45.2% intraosseous and 5.1% on the outer cortex. In this study, artery mean diameter was 0.91 ± 0.31 mm, which was similar to studies of Nicolielo et al. (21) 0.83 ± 0.27 mm, Ilgüy et al. (24) 0.94 ± 0.26 mm and (22) Apostolakis et al. 1.1mm that used CBCT, but studies of Güncü et al. 1.3 mm (17), Kim et al. (19) 1.52mm were higher that used CT.

In this study, 69.81% cases had the artery diameter ≤1mm that was similar tollgüy et al 68.9% (24) and Nicolielo et al. (21) 82%. In the study of Güncü et al. (17) 36.1% and Mardinger et al. (18) 47.4% were ≤1mm, which could be due to differences in CT and CBCT in measurements and the ability of CBCT to detect small diameter arteries to 0.3mm. In this study, the diameter of the PSAA in men was higher than women; these results are consistent with the studies of Ilgüy et al. (24), Güncü et al. (17) and Kim et al. (19). Studies of Nicolielo et al. (21) and Apostolakis et al. (23) did not show such a relationship which can be due to less number of samples or the greater the proportion of female to male in their study population. In this study, artery diameter was increased from the first premolar to the third molar as it was reported in no other studies, which can be the result of measurements at 5 dental area and the greater sample size than other studies. The distance of PSAA to the medial wall of the sinus was decreased with age in present study; this indicates that the maxillary sinus gets smaller with aging. Study of Ilgüy et al. (24) mentioned such a decrease as the mean distance, but in the study of Ilgüy et al. (24) this distance was higher in men than women, in this study there was no significant relationship. Ilgüy et al. (24) examined the artery only in one point on each
side, but this study evaluated it in five dental areas and obtained measurements can be result in differences. Also in the study of Ilgıy et al. (24) the ratio of men to women was 55to 80.

In a study conducted by Hur et al (25), the distance of PSAA to sinus floor for the dental areas were 9.4, 9.7, 10.3, 9.6 and 9.5 mm for first premolar and molar teeth respectively, which was higher than the present study that can be due to much lower number of 42 samples on hemifacial cadavers of Korean population. These amounts in the study of Apostiokakis et al.(23) were 5.9, 5.8, 5.9, 8 and 9.6 mm, which were close to this study. In the present study, the distance of arteries to sinus floor was significantly higher in men, which may be due to the larger sample size in this study and equal gender distribution. The mean distance of PSAA to sinus floor in this study was 7.38±4.13 (0-22.43) mm that was 8.96 mm in Ilgıy et al. (24) study and 7.8±0.3 mm in the study of Güncü et al. (17). The difference could be due to examining five dental areas in the course of artery in the present study. The mean distance of PSAA to alveolar crest in different areas from the first premolar to the second molar in the study of Nicoliclo et al. (21) were 21.9, 18.16, 16.18 and 16.95 mm, respectively; and in the study of Mardinger et al. (18) were 22.55, 19.05, 16.92 and 18.88 mm, which were close results to the present study. These two studies did not measure the third molar area. In the study of Nicolicilo et al. (21) the distance of PSAA to the alveolar crest was higher in the second molar area and significantly superior in women than men that was different from our results; that could be due to smaller sample size and number of women compared with men (33 to 67). In the study of Kim et al. (19), this distance was 18.9±4.21 mm in premolars and 15.45±4.04 in molars without significant difference in age and sex, these results are consistent with our study except the difference in terms of gender in our study. Their sample size was higher (100 male and 100 female), but the data Analysis was done by CT, in the age group between 45 and 65 years; which all can be the reasons for different results. In other studies, regardless of the dental areas in the course of artery, the mean distance of artery to the alveolar crest was 16.88±3.46 mm in Ilgıy et al. (24) study, 17.0±3.53 mm in Kang et al. (26) study, 16.4±3.6 mm in Elian et al. (20) study and 18±4.9±0 mm in Güncü et al. (17) study; the mean distance in this study was 18.13±4.03 mm that higher than other studies which can be due to differences evaluation in the course of PSAA. The mean distance between alveolar crest to sinus floor in Güncü et al. (17) study was 10.2±4.8 mm which is close to this study that was 10.78±4.94 mm.

CONCLUSION
The location of the PSAA relative to Anterolateral wall and floor of maxillary sinus can be variable for anyone and CBCT can be helpful to evaluate it. Due to anatomical variation, evaluation of maxillary sinus using CBCT before sinus augmentation surgery by a surgeon or radiologist can be useful in planning a more precise treatment and avoiding unwanted side effects.

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