

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

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**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  $\leq 1$  mm (68.9%). The prevalence of sinus septa was 55.2%, and that of sinus pathology was 57.4%. The mean age was  $43.07 \pm 17.55$  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.

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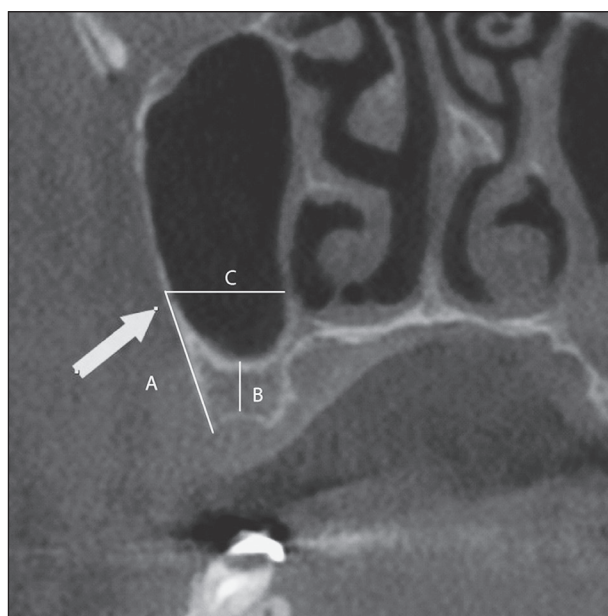
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## Introduction

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.<sup>1,2</sup> Sinus augmentation is a safe procedure with high predictability for rehabilitation of severely atrophic posterior maxillae.<sup>3-6</sup> 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.<sup>7</sup> Assessment of the maxillary sinus anatomy is important to avoid unnecessary complications due to the close anatomical relationship of the PSAA with the

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**Figure 1-** Distance between the lower border of the artery and the alveolar crest (**A**), bone height from the sinus floor to the ridge crest (**B**), and distance from the artery to the medial sinus wall (**C**).

maxillary sinus.<sup>8,9</sup>

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.<sup>10</sup> 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.<sup>11,12</sup> 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 (Imtec 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 (Imtec 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:

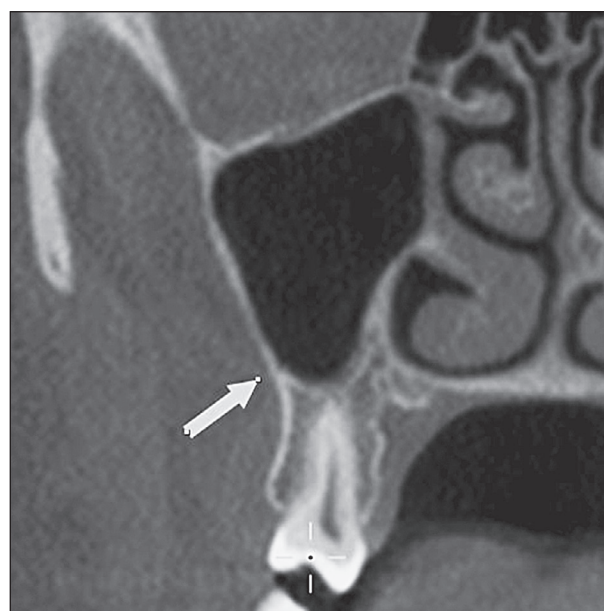
- a. intraosseous (Figure 2),
- b. below the membrane (Figure 3), and
- c. on the outer cortex of the lateral sinus wall (Figure 4).

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

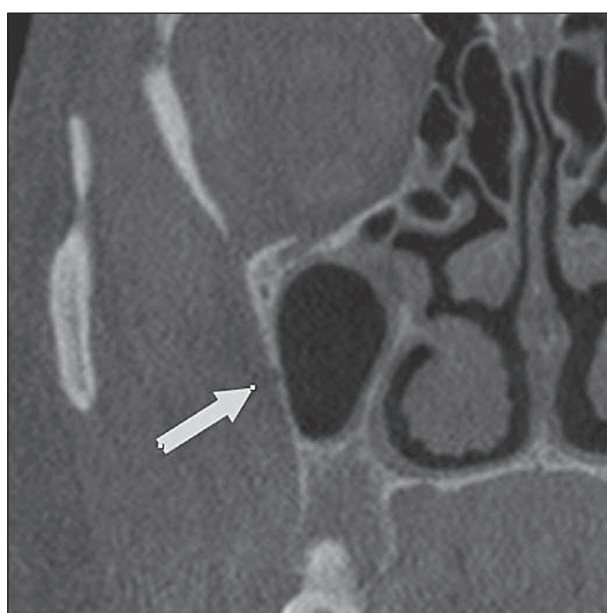
A dentomaxillofacial radiology specialist evaluated the images in a darkened quiet room with dual monitors (HP LP2475W, resolution 1920 × 1200; Hewlett-Packard, Houston, USA). Each viewing ses-



**Figure 2** - Coronal view of the maxillary sinus reveals the intraosseous artery (arrow).



**Figure 3** - Coronal view of the maxillary sinus reveals the artery (arrow), which is below the membrane.



**Figure 4** - Coronal view of the maxillary sinus reveals the artery (arrow), which is on the outer cortex of the lateral sinus wall.

sion lasted 30 minutes. Care was taken to ensure that 24 hours elapsed between all sessions. For intra-examiner calibration and determination of reliability and reproducibility of the measurements, the images were evaluated a second time by the same observer 2 weeks later.

SPSS 15.0 (Statistical Package for Social Sciences, IBM, New York, USA) for Windows 2007 (Microsoft, New Mexico, USA) was used for statistical analysis of the results. Prior to the study, all parameters were evaluated with the Kolmogorov-Smirnov test, and the data were found to be normally distributed. Simple Random Sampling Sample Size Estimation was done. While evaluating the data using descriptive statistical methods, parameters with normal distribution for the comparison of quantitative data were evaluated using one-way analysis of variance, the Tukey test, and Student's t-test. Qualitative data were evaluated using the Chi-square test. The Pearson correlation was used to assess potential correlations between parameters. Intra-observer agreement was calculated using the intraclass correlation coefficient. Significance was accepted at  $p < 0.05$ .

## 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

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

		Absence	Intraosseous	Below the membrane	On the outer cortex of the lateral sinus wall	p value
		n (%)	n (%)	n (%)	n (%)	
Age (years)	20–29	7 (9.0)	55 (70.5)	11 (14.1)	5 (6.4)	0.129
	30–39	1 (2.8)	30 (83.3)	4 (11.1)	1 (2.8)	
	40–49	2 (5.9)	29 (85.3)	3 (8.8)	0 (0.0)	
	50–59	13 (17.6)	43 (58.1)	14 (18.9)	4 (5.4)	
	≥ 60	6 (12.5)	35 (72.9)	3 (6.3)	4 (8.3)	
Gender	Female	17 (10.6)	119 (74.4)	21 (13.1)	3 (1.9)	0.03*
	Male	12 (10.9)	73 (66.4)	14 (12.7)	11 (10.0)	
Edentulous		28 (24.1)	68 (58.6)	12 (10.3)	8 (6.9)	0.00**
Dentulous		1 (0.6)	124 (80.5)	23 (14.9)	6 (3.9)	

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

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  $0.94 \pm 0.26$  mm. The artery diameters were mostly  $\leq 1$  mm (68.9%). The percentages of artery diameters  $\leq 1$  mm were 73.5% and 64.5% for the right and left sinuses, respectively, a difference that was not statistically significant ( $p > 0.05$ ). 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 ( $p < 0.05$ ). 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

**Table 2** - Measurements according to gender.

	Female	Male	p value
	Mean $\pm$ SD	Mean $\pm$ SD	
A**	$16.79 \pm 3.79$	$17.00 \pm 2.94$	0.785
B***	$7.50 \pm 3.03$	$8.34 \pm 3.43$	0.233
C****	$13.27 \pm 2.82$	$14.03 \pm 2.44$	0.031*

\* $p < 0.05$  (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.

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  $16.88 \pm 3.46$  mm (A), and the bone height from the sinus floor to the ridge crest (B) was  $7.84 \pm 3.20$  mm. The mean distance from the artery to the medial sinus wall (C) in dentulous crests ( $13.92 \pm 2.84$  mm) was significantly higher than that measured for the edentulous crest ( $13.00 \pm 2.32$  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 3** - Measurements according to age groups.

	20-29	30-39	40-49	50-59	≥ 60 years	p value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
A**	17.01 ± 3.01	17.52 ± 4.18	17.05 ± 2.93	15.97 ± 3.42	17.40 ± 3.54	0.553
B***	8.29 ± 3.20	9.62 ± 3.28	7.74 ± 1.70	7.65 ± 3.76	7.50 ± 2.92	0.546
C****	14.18 ± 2.48	14.89 ± 2.40	13.00 ± 2.27	12.60 ± 3.05	13.34 ± 2.45	0.001*

\* $p < 0.01$  (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.

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 prevalence of sinus septa was 55.2% and that of sinus membrane thickening was 57.4%. The presence of pathology in men (68.2%) was significantly higher than in females (48.8%;  $p < 0.01$ ).

## Discussion

Sinus augmentation is a method with high predictability for placing successful dental implants into atrophic posterior maxillae.<sup>3-6</sup> 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.*<sup>13</sup> (64.5%), Elian *et al.*<sup>14</sup> (52.9%), Mardinger *et al.*<sup>15</sup> (55%), and Kim *et al.*<sup>16</sup> (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.<sup>15</sup> CBCT provides accurate and reliable linear measurements for reconstruction and imaging of dental and maxillofacial structures.<sup>7-9</sup>

According to Kim *et al.*,<sup>16</sup> 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 ar-

tery from the alveolar ridge was  $16.79 \pm 3.79$  mm for females and  $17.00 \pm 2.94$  mm for males. In anatomic studies, this distance was reported to be 18.9–19.6 mm.<sup>1,2</sup> 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.*<sup>13</sup> (18 mm), Elian *et al.*<sup>14</sup> (16.4 mm), Mardinger *et al.*<sup>15</sup> (16.9 mm), and Kim *et al.*<sup>16</sup> (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  $7.50 \pm 3.03$  mm in females and  $8.34 \pm 3.43$  mm in males. The mean distance from the artery to the antral floor was 9.29 mm in females and 8.66 mm in males. This distance reported by Güncü *et al.*<sup>13</sup> was  $7.8 \pm 0.3$  mm and by Mardinger *et al.*<sup>15</sup> 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.<sup>17</sup> According to our current results, the mean artery diameter was  $0.94 \pm 0.26$  mm. However, Güncü *et al.*,<sup>13</sup> Ella *et al.*,<sup>7</sup> and Kim *et al.*<sup>16</sup> 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.<sup>1,2</sup>

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

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.*<sup>13</sup> and Kim *et al.*<sup>16</sup> reported similar results, Mardinger *et al.*<sup>15</sup> 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.*<sup>13</sup> was 16.1%, by Krennmair *et al.*<sup>18</sup> was 16%, and by Kim *et al.*<sup>19</sup> 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.*<sup>20</sup> report-

ed that the prevalence of sinus septa was 58%, and Neugebauer *et al.*<sup>21</sup> reported that it was 47%. Lana *et al.*<sup>22</sup> 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.*<sup>22</sup> also found that the prevalence of mucosal thickening was 54.8% ( $\leq 3$  mm) and 62.6% ( $\geq 3$  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.*<sup>22</sup> 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.

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