

## Original Research Article

# Evaluation of the Locations of Posterior Superior Alveolar Artery and Lingual Foramen in Cone Beam Computed Tomography Before Dental Implant Treatment

## *Dental İmplant Tedavisi Uygulanacak Hastalarda Tedavi Öncesi Konik Işınli Bilgisayarlı Tomografide Posterior Superior Alvoler Arter ve Lingual Foramenin Lokasyonlarının Değerlendirilmesi*

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### ABSTRACT

**Aim:** This study aimed to evaluate the locations of the lingual foramen and posterior superior alveolar artery (PSAA) and their distances from the alveolar crest and maxillary sinus floor using cone-beam computed tomography (CBCT).

**Materials and Method:** In this study, 136 patients underwent CBCT: 1-The PSAA's proximity to the alveolar crest and sinus floor, 2-Its position on the lateral wall of the maxillary sinus, and 3-The distance from the lingual foramen to the alveolar crest borders.

**Results:** Gender caused a significant difference in the distance of PSAA from the alveolar crest ( $p<0.001$ ). The PSAA was most often located on the inner wall of the maxillary sinus. The distance between the lingual foramen and the lower and upper margins of the crest varied significantly depending on gender ( $p<0.001$ ).

**Conclusion:** In this study, it was found that the lingual foramen, PSAA, and the distances of these formations to the alveolar crests could be determined at a high rate in CBCTs, and gender had an effect on these distances.

**Keywords:** Anatomic variation; Cone beam computed tomography; Mandible; Maxillary sinus

### ÖZET

**Amaç:** Bu çalışmanın amacı konik ışınli bilgisayarlı tomografi (KİBT)'de lingual foramen ve posterior superior alveoler arter (PSAA)'nın lokasyonları, bunların alveol kret ve maksiller sinüs tabanına olan mesafelerinin değerlendirilmesidir.

**Gereç ve Yöntem:** Çalışmada 136 hasta KİBT'sinde sırasıyla; 1-PSAA'nın alveoler kret ve sinüs tabanına mesafeleri, 2-PSAA'nın maksiller sinüs lateral duvarındaki lokasyonları, 3-lingual foramenin alveol kret sınırlarına mesafesi incelendi.

**Bulgular:** Çalışmada cinsiyetin PSAA'ın alveol kret ile olan mesafesinde anlamlı farklılık oluşturduğu görüldü ( $p<0.001$ ). PSAA'nın maksiller sinüs lateral duvarındaki lokasyonunda en sık iç duvarda konumlandığı görüldü. Cinsiyetin lingual foramenin lokasyonunun kretin alt ve üst sınırına mesafesi arasında anlamlı farklılık oluşturduğu belirlendi ( $p<0.001$ ).

**Sonuç:** Çalışmada lingual foramen, PSAA, bu oluşumların alveol kretlere olan mesafelerinin KİBT'lerde yüksek bir oranda belirlenebildiği aynı zamanda cinsiyetin bu mesafelere etkisinin olduğu bulundu.

**Anahtar Kelimeler:** Anatomik varyasyon; Konik ışınli bilgisayarlı tomografi; Maksiller sinüs; Mandibula

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## INTRODUCTION

Today, the purpose of dentistry is to provide optimum aesthetics, functionality, and phonation to patients. Although conservative approaches are the first treatment options that come to mind in dental treatments, radical treatments are sometimes performed instead of conservative approaches; tooth extraction is inevitable.<sup>1</sup> The use of dental implants in the prosthetic rehabilitation of recently lost teeth has become widespread worldwide.<sup>2</sup>

There are a few important points that dentists should consider for dental implant applications. The dimensions, quality, density, and relationship of alveolar bone with anatomical formations are some of these points. Radiographic evaluation is as important as clinical examination in the implantology field. The bone content, morphology, and position of anatomical structures can be determined by radiographic evaluations.<sup>3</sup>

Owing to tooth loss in the maxillary posterior region, the amount of residual alveolar bone often becomes insufficient for implant placement because of physiological bone resorption. In such cases, bone augmentation via lateral sinus surgery is necessary. In lateral sinus surgery, the window is opened in the sinus wall, the Schneiderian membrane is lifted using sinus elevators, and bone augmentation is performed.<sup>4</sup>

The Schneiderian membrane is supplied by the posterior superior alveolar artery (PSAA) branch of the maxillary artery and the infraorbital artery (IOA) branches. During lateral sinus floor augmentation, hematoma may occur if the PSAA is damaged. Hematoma formation is one of the most common complications of maxillary sinus augmentation. This bleeding can lead to compromised during the procedure, infection of the graft material, and ultimately, an unsuccessful augmentation protocol.<sup>5, 6</sup>

The lingual foramen is typically observed in the midline of the mandible, below the apical aspect of the incisors, as a radiopaque, well-demarcated, single-round radiolucency. Severe bleeding may occur due to lingual cortex perforation, lingual artery, or submental artery injuries during surgical procedures such as implant application in this area. It has been reported that such hematomas that may occur

during implant application may cause life-threatening results by obstructing the respiratory tract.<sup>7, 8</sup>

Radiographic imaging in dentistry provides important information for diagnosis and treatment planning. Until recently, 2D radiographic imaging methods, such as periapical and panoramic films, have been used for implant surgery; however, cone-beam computed tomography (CBCT) has been preferred. The most important advantages of CBCTs are that they provide more detailed information about the bony structures and provide more precise planning in implantology.<sup>9</sup>

The purpose of this study was to identify the locations of anatomical structures, namely the PSAA and the lingual foramen, which may result in intraoperative and postoperative complications during implant surgery. To achieve this goal, this study investigated the relationship between PSAA and the maxillary sinus, as well as the association of PSAA and the lingual foramen with alveolar crests.

## MATERIALS AND METHOD

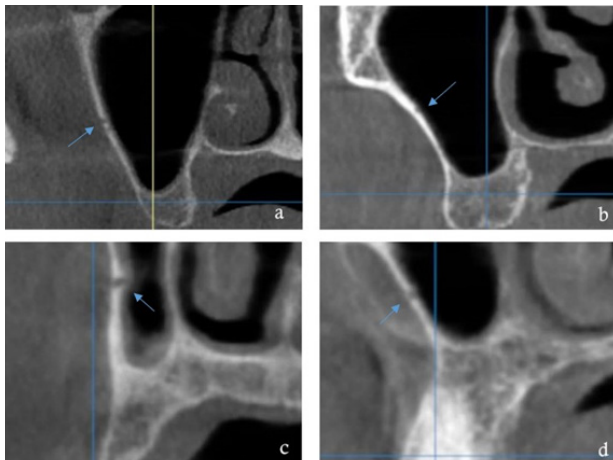
This study was approved by the Scientific Research and Publication Ethics Committee of Nuh Naci Yazgan University (decision number 2023/001-006). The study adhered to the ethical standards of the committee responsible for human experiments (institutional and national) and the 1975 Declaration of Helsinki revised in 2008. The study population consisted of patients seeking implant treatment for missing teeth at Nuh Naci Yazgan University Faculty of Dentistry. Before implant treatment, images were taken from the patients in the same standard stance and with the same radiographic parameters, with the Frankfurt horizontal plane parallel to the ground and the vertical axis passing through the midline. Study data were obtained by retrospective analysis of these images. The evaluations were performed by a periodontologist. All data were evaluated on the same computer screen in a dimly lit and quiet room. After all, evaluations were completed, 25% were randomly selected from each sample group and re-evaluated under the same conditions, ensuring intra-observer reliability.

The anatomical locations were determined using CBCT scans of the upper and lower maxilla of 140 patients (70 women and 70 men). The study pro-

ceeded with data from 136 patients, as CBCT data for four patients could not be accessed. The study reviewed CBCT scans of 69 male and 67 female patients with a mean age of  $52.5 \pm 11.2$  years, a minimum age of 22 years, and a maximum age of 75 years.

In the study, patient information was evaluated, which included:

1. Age
2. Gender
3. Anatomical formations examined in the CBCT, including:
  - 3.1 Distance between the right and left PSAA and the alveolar crest apex
  - 3.2 Right and left PSAAs distances from the floor of the maxillary sinus
  - 3.3 Position of the right and left PSAA in the lateral wall of the maxillary sinus in the maxilla<sup>10</sup> (Figure 1).
4. The study also evaluated the following anatomical formations in the mandible:
  - 4.1 Localization of the lingual foramen
  - 4.2 The distance between the lingual foramen and the upper and lower bone crest borders.<sup>10</sup>



**Figure 1.** The location of the PSAA in the maxillary sinus wall is shown with a blue arrow. (a) PSAA embedded in the outer wall of the maxillary sinus, (b) PSAA embedded in the inner wall of the maxillary sinus, (c) intraosseous PSAA, (d) transosseous PSAA.

### Statistical Analyses

Data analysis was performed using TURCOSA (Turcosa Analytics Ltd Co, Turkey, [www.turcosa.com.tr](http://www.turcosa.com.tr)) statistical software. Qualitative variables were analyzed using frequency analysis, while descriptive statistics were used for quantitative variables. Normal

distribution was evaluated using the Shapiro-Wilk test and histogram graph. The Mann-Whitney U test was used to determine the association between the quantitative variables and gender. The relationship between the qualitative variables was examined using the chi-squared test. Multiple comparisons were corrected using the Bonferroni correction. Statistical significance was set at  $p < 0.05$ .

### RESULTS

The results of all parameters evaluated in the present study were as follows: the right PSAA was located at 16.9% on the outer wall, 39% on the inner wall, 19.9% intraosseous, and 24.3% transosseous; the left PSAA was located at 6.6% on the outer wall, 50% on the inner wall, 16.2% on the intraosseous, and 27.2% transosseous. The lingual foramen was located at the midline in all patients (Table 1).

There was a statistically significant difference in the distance of the left PSAA from the crest between the sexes. The distance of the left PSAA to the crest was higher in males (21.5 mm) than in females (20.5 mm) ( $p < 0.001$ ) (Table 2). There was a statistically significant difference in the distance from the lingual foramen to the upper border of the bone crest between the genders. The distance from the lingual foramen to the upper border of the bone crest was higher in men (21.8 mm) compared to women (18.1 mm) ( $p < 0.001$ ) (Table 2). There was a statistically significant difference in the distance from the lingual foramen to the lower border of the bone crest between the genders. The distance from the lingual foramen to the lower border of the bone crest was higher in men (12.8 mm) compared to women (11.6 mm) ( $p = 0.001$ ) (Table 2).

The position and significance of PSAA was demonstrated to be significantly correlated in comparison of the right and left sides using the chi-square test ( $p < 0.001$ ). Additionally, there was a significant difference in intraosseous-transosseous bone loss ( $p < 0.001$ ). The results are presented in Table 3 and Figure 2, respectively.

**Table 1.** Frequency analysis of qualitative data

		n	%
<b>Gender</b>	Male	69	50.7
	Female	67	49.3
<b>Posterior superior alveolar artery (PSAA) location-RIGHT</b>	Outer wall	23	16.9
	Inner wall	53	39
	Intraosseous	27	19.9
	Trans osseous	33	24.3
<b>Posterior superior alveolar artery (PSAA) location- LEFT</b>	Outer wall	9	6.6
	Inner wall	68	50
	Intraosseous	22	16.2
	Trans osseous	37	27.2
	<b>Lingual foramen location</b>	Midline	136

**Table 2.** Comparison of the lingual foramen's distance from the upper and lower alveolar crest borders, the posterior superior alveolar artery's (PSAA) distance from the sinus floor, and these measurements between genders

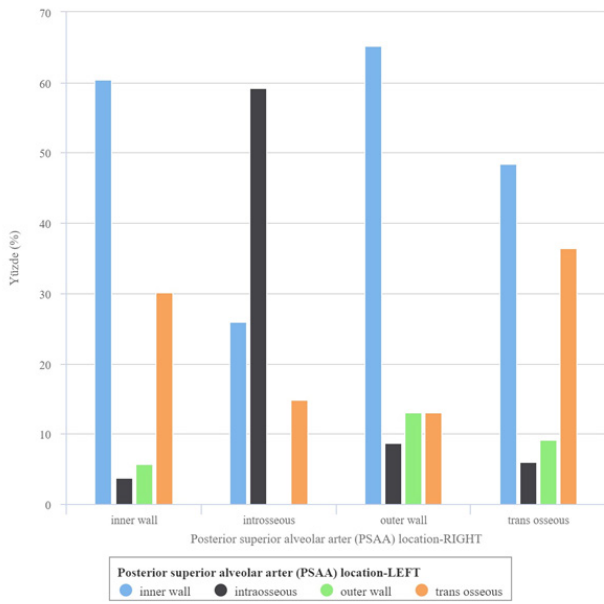
	Male (n: 69) Mean±Sd (Min-Max)	Female (n: 67) Mean±Sd (Min-Max)	Total (n: 136) Mean±Sd (Min-Max)	p value*
<b>PSAA- alveolar crest distance right</b>	21±4.2 (12.2-37.5)	20.1±3.1 (13.7-29.1)	20.6±3.7 (12.2-37.5)	0.114
<b>PSAA distance to sinus floor right</b>	12.3±4.6 (4.8-26.5)	11.04±2.9 (4.3-19.1)	11.7±3.9 (4.3-26.5)	0.166
<b>PSAA-alveolar crest distance left</b>	21.01±3.3 (13.3-27)	18.7±4.3 (2.08-26.4)	19.9±4 (2.08-27)	<b>&lt;0.001</b>
<b>PSAA distance to sinus floor left</b>	11.5±2.8 (5.8-19.6)	10.5±2.5 (4.7-14.8)	11.03±2.7 (4.7-19.6)	0.072
<b>The distance between the lingual foramen and the peak of the bone crest</b>	21.1±3.1 (14.3-27.1)	18.5±4 (9-26.5)	19.8±3.8 (9-27.1)	<b>&lt;0.001</b>
<b>Distance of the lingual foramen from the lower border of the bone crest</b>	12.6±2.3 (6.3-16.8)	10.9±3.08 (3.8-15.8)	11.03±2.7 (4.7-19.6)	<b>0.001</b>

\*Mann-Whitney U test was used for gender comparison. p<0.05 showed statistical difference and is shown in bold font.

**Table 3.** Determination of the relationship between the right and left half skull localizations of the posterior superior alveolar artery

			Posterior superior alveolar artery (PSAA) location- Left					Test statistic (Chi-squared)
			Outer wall	Inner wall	Intraosseous	Trans osseous	Total	
<b>Posterior superior alveolar artery (PSAA) location-Right</b>	<b>Outer wall</b>	Count(%)	2 (1.5)	15 (11)	2 (1.5)	4 (3)	23 (17)	<b>&lt;0.001*</b> 42.1266
	<b>Inner wall</b>	Count(%)	4 (3)	30 (22)	3 (2.2)	16(11.8)	53 (39)	
	<b>Intraosseous</b>	Count(%)	0 (0)	7(5.2)	15 (11)	5(3.7)	27 (19.9)	
	<b>Trans osseous</b>	Count(%)	3 (2.2)	16(11.8)	2 (1.5)	12(8.8)	33 (24.3)	
	<b>Total</b>	Count(%)	9 (6.7) <sup>a</sup>	68 (50) <sup>a</sup>	22 (16.2) <sup>b</sup>	37 (27.2) <sup>a</sup>	136 (100)	

\*Chi-square test was used to determine the relationship between qualitative variables. Bonferroni correction was used in multiple comparisons. The relationship between pairwise comparisons was indicated as a superscript in the total value.



**Figure 2.** Graphical representation of the various localizations of the PSAA on both the right and left sides of the skull.

## DISCUSSION

In our study, which examined CBCT scans of 136 patients, we identified the locations of the PSAA and lingual foramen, which are frequently associated with implantology complications. Our findings revealed gender-related differences in two parameters: the distance between the PSAA and crest and the distance between the lingual foramen and the lower and upper crest margins. Additionally, we observed that PSAA was most commonly located in the inner wall when its course in the maxillary sinus was examined.

PSAA and IOA are branches of the maxillary artery that are given off before it enters the pterygomaxillary fissure. The lateral wall of the maxillary sinus is supplied by these branches. Their courses along the lateral walls can change from intraosseous to extraosseous, and vice versa. Over time, the maxillary sinuses undergo pneumatization, which results in a decrease in alveolar crest height. Sinus lift procedures may be necessary when placing implants in the posterior region. During complex surgical procedures, injury to the PSAA can cause serious bleeding. This bleeding can obscure the view during the operation and can result in perforation of the Schneiderian membrane during sinus lift procedures. Damage to the membrane is a complication that can

make the operation more difficult. Therefore, a good understanding of the basic anatomy and preoperative assessment of the PSAA is important to avoid this complication.<sup>11</sup> In our study, we utilized the classification system proposed by Lee *et al.*<sup>12</sup> to categorize the location of PSAA. This system includes three types of locations: Type I, where the PSAA is embedded in the bone in the lateral wall of the maxillary sinus; Type II, which is located in the lateral wall of the maxillary sinus, but in an intraosseous location; and Type III, where it is located outside the lateral wall of the maxillary sinus in the outer wall location. We determined our study groups by creating a new group in addition to this classification as a transosseous transition in cases where PSAA made a trans transition from the outer wall of the maxillary sinus.

A lot of studies have been conducted on PSAA. In a study by Güncü *et al.*<sup>13</sup>, in which they determined the location of PSAA in the maxillary sinus, Lee *et al.*'s<sup>12</sup> classification was used and stated that PSAA is mostly located in the inner wall in this study. Keçeli *et al.*<sup>14</sup> and Danesh *et al.*<sup>15</sup> used the same classification, and as a result, it was observed that PSAA showed the most course in the inner wall, in line with our study.

In our investigation, we found no variations in the progression of PSAA between both the right, or left maxillary sinuses. Khojastepour *et al.*<sup>16</sup> showed that there was no significant difference in the course of PSAA in the right and left sinuses in a different study. This finding in our study was found to be compatible with the literature.

In our research, we found a statistically significant distance difference associated with gender between the PSAA and alveolar crest floor in the left maxillary region. However, the distance between the sinus floor and the PSAA was statistically insignificant. This finding contrasts with the results of previous studies by Lozano *et al.*<sup>17</sup>, Tehranchi *et al.*<sup>18</sup>, and Pandharbale *et al.*<sup>19</sup>, who did not find a significant gender-related difference in the distance between the PSAA and alveolar crest. According to the study by Velasco-Torres *et al.*<sup>20</sup>, there is a statistically significant difference in the distance between PSAA and the alveolar crest between genders.

The mandible contains various unnamed accessory foramina on the lingual side, allowing passage for nerves and blood vessels. The symphysis region of the mandible is an important site for surgical procedures such as dental implants, bone grafting, osteosynthesis plate placement, tori removal, and genioplasty. This area plays a crucial role in implant rehabilitation for edentulous patients. The interforaminal region has traditionally been considered a safe area for implant surgery, although sensitivity issues have been reported following implant surgery or bone harvesting. Occasionally, significant bleeding and hematomas have been described in the literature resulting from vascular lesions at the lingual foramen during implant surgery. These lesions can also affect mylohyoid nerve branches, leading to paresthesia or hypoesthesia. These findings highlight the importance of identifying the mandibular lingual foramina and its associated neurovascular structures.<sup>21</sup>

In our study, we identified the lingual foramen in all 136 CBCT scans that were analyzed. This finding is consistent with those of previous studies such as that conducted by Liang *et al.*<sup>22</sup>, in which at least one lingual foramen was detected in 49(98%) of 50 dry human mandibles. No lingual foramen was observed. On the other hand, Babiuc *et al.*<sup>23</sup> Attempted to determine the location of the lingual foramen in 68 mandibles and successfully identified it in 66 of them.

In this research, we found that the distance between the coronal and apical areas to the alveolar crest of the lingual foramen varied statistically significantly according to gender. In contrast, Genç<sup>24</sup> found that these values differed between male and female populations, but the difference was not statistically significant. This suggests that gender-related differences in the distance between the coronal and apical regions of the alveolar crest of the lingual foramen may vary depending on the study population and measurement methods used.

With advancements in imaging techniques, the detection of PSAA in CBCT scans has become increasingly common. Previous studies have reported a wide range of detectability rates for PSAA ranging from 60% to 99%. These variations in detectability may be attributed to differences in imaging parameters, patient populations, and observer experienc-

es.<sup>25</sup> In our study, the detectability of PSAA in CBCT scans was >95%, which is consistent with the success rates reported in previous studies. This high success rate may be attributed to the imaging parameters used in our study, the patient population, and the experience of the observers who analyzed the CBCT scans.

This study has two important limitations. First, while we investigated the locations of the two anatomical structures known to be important in implantology, more CBCT parameters need to be examined to reach a comprehensive understanding of implantology. Second, a more comprehensive analysis could be performed by forming subgroups based on whether the maxillary posterior region was edentulous or contained teeth when determining how far the PSAA is from the crest's base.

## CONCLUSION

In light of the current analyses, the results of this study indicate that both anatomical structures (PSAA and lingual foramen) are identifiable on CBCT scans. Furthermore, the distances between the PSAA and sinus floor, and the distances between the lingual foramen and the lower and upper borders of the alveolar crest showed significant gender differences. These findings may help to guide implant placement and reduce the risk of complications. However, further research is needed to confirm these results and investigate other relevant parameters in CBCT.

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