

Original Article

Position of posterior superior alveolar artery in relation to the maxillary sinus using cone beam computed tomography in Indian sub-population

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Abstract – Purpose: To assess the location of posterior superior alveolar artery (PSAA) using CBCT in relevance to sinus lift procedure for implant placement. **Patients and Methods:** A retrospective study was conducted using the CBCT data of 500 patients ($n=500$). Linear measurements were carried out to localize the medio-lateral and vertical position of posterior superior alveolar artery in postero-lateral wall of maxillary sinus and its proximity to the floor of maxillary sinus using CS 3D imaging 3.7.0 software program. The relative position of PSAA was determined as; (a) intra-osseous, (b) below the membrane and (c) outer-cortex of lateral sinus wall. The location of PSAA was assessed in molar region bilaterally by using following radiographic measurement; (1) distance between the lower border of posterior superior alveolar artery and alveolar crest, (2) height from the floor of maxillary sinus to alveolar crest and (3) distance from the posterior superior alveolar artery to medial wall of maxillary sinus. **Results:** The prevalence of the artery was observed in 99.4% of the sinuses and was mostly intraosseous (84.2%). The mean distance between the lower border of the artery and alveolar crest is significantly higher in males compared to females ($P < 0.01$). The distribution of artery location did not differ significantly across various age groups ($P > 0.05$). **Discussion/Conclusion:** The most common variant of PSAA was identified in the intra-osseous region and the mean distance of the vessel to crest of the residual ridge differs significantly with gender and not with age.

Introduction

The treatment protocol for prosthetic rehabilitation in the posterior maxilla is often complicated as bone resorption commonly precedes or accompanies tooth loss. Deficient posterior alveolar ridge along with increased pneumatization of the maxillary sinus makes it a surgically challenging zone for implant supported prosthesis [1,2]. The maxillary sinus is bordered superiorly by floor of the orbit, medially by the nasal cavity, anteriorly by infratemporal surface of the maxilla and inferiorly by alveolar and palatine processes of the maxilla [3]. It extends from the first premolar to the third molar and is lowest in the first and second molar region [4]. The mean distance between the maxillary posterior teeth and the floor of the sinus is about 1.97 mm [5].

The antral anatomy is intricate since primary as well as secondary septa may be present in the maxillary sinus, however their location may vary. Around 22.5–22.7% septa are found in

the posterior region with a height ranging from 2.5 to 6.0 mm [6]. The sensory innervation of the maxillary sinus is provided through the infraorbital and anterior, middle, and posterior superior alveolar branches of the maxillary nerve (V2) [3]. Vascular supply is derived from branches of the maxillary artery; the posterior superior alveolar artery (PSAA), the infraorbital artery, and the posterior lateral nasal artery [7]. The PSAA and infraorbital artery (IOA) supply the lateral sinus wall and its overlying membrane [8]. PSAA is in close contact with bone and periosteum with a maximum diameter of 2 mm. Its course can either be straight (78.1%) or U shaped (21.9%) [9]. Due to the complex anatomy of this region and pneumatization following tooth loss, variations are noted in the prevalence and course of these vital structures. Factors such as age, gender, dentition status, and sinus volume may also influence the location of the neurovascular bundle [10].

The anatomical relations of these vessels are an important concern in implantology as well as other oral surgical procedures. Haemorrhage is one of the most commonly reported complications which occurs mainly due to trauma

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to the intramural artery, an anastomoses between the infraorbital artery and the posterior superior alveolar artery, frequently located on the lateral wall, the site in which the surgeon makes a bony window to reach the antral cavity [11–13]. PSAA is a crucial structure located on the lateral wall of maxillary sinus and due to its small diameter, the vessel is very frequently missed in pre-operative radiographic assessments which magnifies the risk of possible complications. Hemorrhage has been reported due to arterial damage in case reports by Jensen *et al.* and Lee [14,15]. It is therefore necessary to have a thorough knowledge of the vascular anatomy and correlate it radiographically to minimize the risk of bleeding and hematoma in emergency situations [16,17].

Limited data is available to assess the location of this artery in edentulous maxillae in Indian sub-populations. Hence, this study was undertaken, to assess the position of PSAA in relation to the maxillary sinus using cone beam computed tomography in the Indian sub-population. The primary objective of this study is to assess the prevalence of PSAA in posterior partially edentulous maxillary CBCT and to determine its position with respect to different anatomic reference points. The secondary objective of this study is to correlate these findings according to age and gender. The null hypothesis is that there is no statistical difference in the prevalence and location of PSAA among different age groups and genders.

Patients and methods

A retrospective study was conducted using the CBCT data of patients who reported to our institute for treatment. The study design was approved by the institutional review board and a written consent was obtained from each patient to access their CBCT data for research. A random sample of 500 CBCT scans of missing maxillary molar/s was obtained from the Department of Oral Radiology. In order to detect the clinically significant differences of the artery location in the given subpopulation, sample size (n) of 500 CBCT scans provided 80% power with 5% level of significance. The patients ranged between 25 and 60 years of age and were further divided into male and female subgroups.

The CBCT scans of posterior partially edentulous maxillae were obtained from Kodak CS 9300 (Carestream Dental, Atlanta, United States) dental imaging system. Linear measurements were carried out to localize the medio-lateral and vertical position of posterior superior alveolar artery in postero-lateral wall of maxillary sinus and its proximity to the floor of maxillary sinus using CS 3D imaging 3.7.0 software program. The exposure settings during the scan included 60 kVp, 12 mA, voxel size 0.2 mm and FOV 11 × 5 cm with an exposure time of 15 s. Reformatting of the 3D reconstructions were created by using the axial CBCT scans on local workstation using CS 3D imaging 3.7.0 dental imaging software. The cross-sectional images were obtained with 1 mm of slice thickness. The scans were re-examined after 2 weeks by the same observer for the determination of reproducibility and reliability of the linear

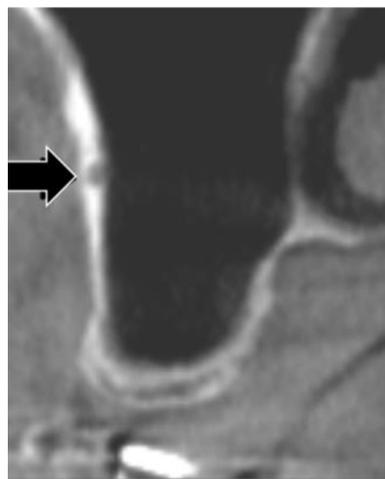


Fig. 1. Intraosseous variety of PSAA.



Fig. 2. Below the membrane variety of PSAA.

measurements and the location of neuro-vascular bundle. A mean value of the two readings obtained was accepted as the final measurement.

Prior to the procedure of locating the posterior superior alveolar artery and measurements, each CBCT scan was oriented. The coronal sections of the edentulous first molar region in maxillary scans were evaluated for the optimal visualization of the neuro-vascular bundle in postero-lateral wall of maxillary sinus. The radiolucent neuro-vascular bundle was evaluated on coronal section where it first appeared in first/second molar region. The relative position of PSAA to medio-lateral wall of maxillary sinus was determined as; (a) intra-osseous, (b) below the membrane and (c) outer-cortex of lateral sinus wall (Figs. 1–3).

The location of PSAA was assessed in molar region by using following measurements:

– Distance between the lower border of posterior superior alveolar artery and alveolar crest (Fig. 4)

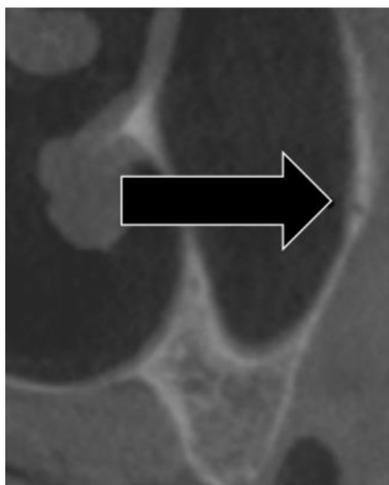


Fig. 3. Outer cortex of lateral sinus wall variety of PSAA.

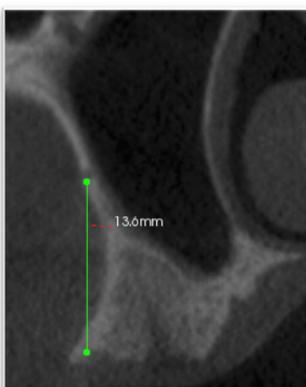


Fig. 4. Distance between the lower border of the artery and alveolar crest.

- Height from the floor of maxillary sinus to alveolar crest (Fig. 5)
- Distance from the posterior superior alveolar artery to medial wall of maxillary sinus (Fig. 6).

Data was analysed using SPSS version 21.0 (IBM Corporation, New York, USA). Distribution of artery localization and radiographic measurements according to age and gender were carried out using Chi Square test and one-way ANOVA test respectively. $P \leq 0.05$ was considered as statistically significant.

Results

A total of 500 (270 males, 230 females) CBCT scans of patients ranged between 25 and 60 years of with missing maxillary molars were evaluated. The prevalence of PSAA reported in this study was 99.4%, observed in the following positions:

- intra-osseous 84.2%,

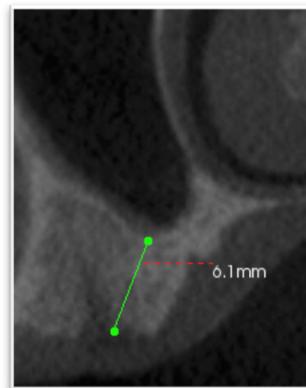


Fig. 5. Bone height from the sinus floor to the ridge crest.

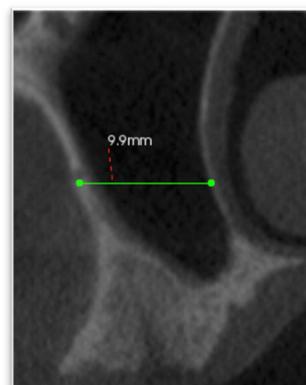


Fig. 6. Distance from the artery to the medial sinus wall.

- below the membrane 12%,
- outer cortex of lateral sinus wall 3.2%.

These findings were consistent through all the test age groups for both the genders. No significant differences were noted. A detailed description of the distribution of artery localization and radiographic measurements according to age and gender are described in Tables I and II respectively.

Artery localisation was commonly observed in the intra osseous region of all the age groups for both the genders. The mean distance between the lower border of the artery and 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) did not differ significantly across five age groups of the cases studied ($P > 0.05$). The mean distance between the lower border of the artery and alveolar crest (A) was significantly higher in males compared to females ($P < 0.01$). The mean bone height from the sinus floor to the ridge crest (B) and the distance from the artery to the medial sinus wall (C) did not differ significantly between male and female cases studied ($P > 0.05$).

Discussion

Sinus graft surgeries are commonly planned to reconstruct and rehabilitate the edentulous posterior maxilla afflicted with alveolar bone loss post-extraction and sinus pneumatization

Table I. Distribution of artery localization according to age and gender (Chi square test).

Parameters	Artery localization				P-value	
	Absence	Intra-osseous	Below the membrane	On the outer context of the lateral sinus wall		
Age group (years)	<30 (<i>n</i> = 16)	0	13 (81.3)	3 (18.8)	0	0.446 NS
	30–39 (<i>n</i> = 55)	0	44 (80.0)	9 (16.4)	2 (3.6)	
	40–49 (<i>n</i> = 60)	0	58 (93.3)	1 (1.7)	3 (5.0)	
	50–59 (<i>n</i> = 201)	2 (1.0)	164 (81.6)	27 (13.4)	8 (4.0)	
	60–69 (<i>n</i> = 168)	1 (0.6)	144 (85.7)	20 (11.9)	3 (1.8)	
Gender	Male (<i>n</i> = 270)	3 (1.1)	224 (83.0)	34 (12.6)	9 (3.3)	0.413 NS
	Female (<i>n</i> = 230)	0	197 (85.7)	26 (11.3)	7 (3.0)	

Table II. Comparison of mean radiographic measurements according to age and gender (One-way Anova test).

Parameters	Mean distance (mm)						
	Distance between the lower border of the artery and alveolar crest		Bone height from the sinus floor to the ridge crest		Distance from the artery to the medial sinus wall		
	Mean	SD	Mean	SD	Mean	SD	
Age group (years)	<30 (<i>n</i> = 16)	16.21	3.26	10.03	2.59	13.62	4.86
	30–39 (<i>n</i> = 55)	17.45	3.98	9.40	3.07	14.10	3.10
	40–49 (<i>n</i> = 60)	17.27	3.76	9.96	2.79	13.12	3.92
	50–59 (<i>n</i> = 201)	17.18	3.77	9.53	2.90	12.68	3.87
	60–69 (<i>n</i> = 168)	17.83	4.39	9.86	2.97	12.93	4.23
P Value	0.400 NS		0.667 NS		0.196 NS		
Gender	Male (<i>n</i> = 270)	17.84	4.21	9.78	2.83	13.08	4.14
	Female (<i>n</i> = 230)	16.91	3.68	9.60	3.02	12.91	3.77
P Value	0.009 **		0.495 NS		0.631 NS		

** Highly significant.

[18,19]. However, perforations of the Schneiderian membrane followed by haemorrhage are the most commonly encountered complications during these procedures. The variable location of the vascularization of the latero-posterior walls of the sinus as well as the Schneiderian membrane result in increased risk of haemorrhage. Intraoperative haemorrhage not only reduces the visibility and hampers the surgical procedure but also increases the risk of postoperative hematoma, subsequent infection and complete loss of the graft [20]. In order to avoid potential complications during sinus lift surgery the vascular network of the maxillary sinus should be fully understood [21]. In case of any suspected complications during sinus lift procedure with lateral window technique, the artery can be isolated using double window technique described by Maridati *et al.* Alternatively, the size and the position of the lateral window and the extent of its superior border can be limited according to the localisation of the artery on the CBCT [22].

The posterior superior alveolar artery is located on the lateral wall of the maxillary sinus and is present at the site where the lateral window is created for sinus floor elevation techniques in around 10–30% cases.

Use of 3-dimensional planning can help in avoiding an encounter with the artery. At a considerably lower radiation dose, CBCT is an effective tool in visualization of PSAA, compared to conventional computed tomography. Although the location of the artery may vary, it can be effortlessly identified as having an intraosseous or sub-membranous course through the scans [23].

Cadaveric studies confirm the presence of the artery in 100% of the cases [8]. In this study, the prevalence of the artery was observed in 99.4% of the sinuses and was mostly intraosseous (84.2%) followed by below the membrane (12%) and outer cortex of lateral sinus wall (3.2%). The success rate for identifying the artery was higher than that reported by Velasco-Torres *et al.* (83–86%), Tehranchi *et al.* (87%) and Anamali *et al.* (92.7%) [10,24,25]. Tehranchi *et al.* located the artery beneath the sinus membrane in 47% of cases and intraosseous in 47% of cases which varied from the results of this study [24]. However, similar results were found in a study conducted by Chitsazi *et al.* and Ilguy *et al.* in which the position of the artery was intraosseous in 73.2% and 71.1% respectively [26,27].

The results of the mean radiographic measurements of the current study are discussed as follows:

- The mean distance between the lower border of the artery and the alveolar crest was recorded to understand the position of the artery with respect to the crest of the residual alveolar ridge. This would be useful in determining the risk of possible complications with the height of implant planned or the extent of sinus elevation required. In the current study, this mean height was 17.37 ± 3.94 mm. These results were concurrent with other published studies by Tehranchi *et al.* 16.7 ± 3.96 mm and Chitsazi *et al.* 16.17 ± 1.63 and differed from those reported by Velasco-Torres *et al.* (13.40 ± 3.72 mm) [10,24,26].
- The mean bone height from the sinus floor to the ridge crest recorded in this study was 9.69 ± 2.92 mm. The rationale behind this measurement was to evaluate the mean height of edentulous ridge in the posterior maxilla. Also, the difference of the first two measurements (mean distance between the lower border of the artery and the alveolar crest – mean bone height from the sinus floor to the ridge crest) would help in risk assessment with respect to the location of the artery. However, smaller values have been reported in literature [28].
- The mean distance from the artery to the medial sinus wall was 12.99 ± 3.65 mm in this study. This reading was incorporated to ensure a two point location of the artery and the medial sinus wall can be considered as a more stable landmark for evaluation of the medio-lateral position of the artery. Similar results were published by Ilguy *et al.* 13.92 ± 2.84 mm in dentulous and 13.00 ± 2.32 mm in edentulous Turkish population [27]. These results are in disagreement with those reported by Pandharbale *et al.* (15 ± 0.5 mm) [23].

Population variability, sample composition, different measurement equipment and techniques, varying height of the residual bony ridge, maxillary atrophy, variations in edentulous sites and presence of systemic conditions leading to extensive resorption are a few possible reasons for inconsistencies amongst the results of these studies.

Kim and co-workers noted gender dimorphism in the prevalence of this artery [29]. On the contrary, no significant correlation was found between gender and the appearance of the artery in this study. These results are in agreement with those reported by Ilgüy *et al.* [27].

The distance from the base of the artery to the alveolar crest differed significantly between the genders ($P=0.009$) in this study, unlike that reported by Velasco-Torres *et al.* [10] Tehranchi *et al.* found statistically significant ($P < 0.05$) differences between males and females similar to this study [24]. This discrepancy could be attributed to differences in the vertical height of the alveolar ridge and the variable rates of resorption among males and females. The mean distance from the lower border of the artery to the alveolar crest is lesser in females; indicating a higher risk of complications during the preparation of the lateral window caused by injury to the artery

[24]. This might be due to variation in the age of females in the selected samples; as the literature suggests post menopause, estrogen depletion leads to an increased rate of bone resorption.

There were no significant differences between the five age groups for the prevalence of the artery as well as various radiographic measurements. Similar findings have been reported in the literature [10]. However, a positive correlation has been emphasized between the diameter of the artery and age. Since, the diameter of PSAA is relatively greater in elder individuals, they maybe at a greater risk of surgical complications [10].

The relation of posterior superior alveolar artery to maxillary sinus is extremely important especially in terms of its location and distance to the ridge crest. Correct diagnosis, proper 3D treatment planning and the knowledge of surrounding anatomies could greatly reduce the uneventful incidence of surgical complications.

Conclusion

The most common variant of PSAA was identified in the intra-osseous region and the mean distance of the vessel to crest of the residual ridge differs significantly with gender and not with age.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Conflicts of Interests

The authors had no conflict of interests.

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