Original Article

Assessment of neurovascular channels in lateral maxillary sinus wall using cone-beam computed tomography: An imperative clinicians guide for implant placements

ABSTRACT

Background: The aim of this study is to evaluate the location and radio morphometric features of the posterior superior alveolar artery (PSAA) in patients undergoing rehabilitation of posterior maxilla and other sinus augmentation surgical procedures by cone-beam computed tomography (CBCT).

Materials and Methods: A total of 816 CBCT scans were included. Various radio morphometric measurements were done to assess the PSAA location, diameter, and distances to the sinus floor and alveolar crest.

Results: The PSAA was mostly intraosseous in the maximum in the age group 31–51 years (56%), in males (53.4%), and in dentate patients (57.4%). The artery tends to be wider in older patients. Distances to the sinus floor or the alveolar crest tend to be shorter in women.

Conclusions: This study suggests that CBCT is a valuable pre-surgical tool and the evaluation of the PSAA on CBCT images could reduce the likelihood of excess bleeding during surgery in the maxillary posterior region.

Keywords: Alveolar antral artery, cone-beam computed tomography, maxillary sinus, posterior superior alveolar artery

INTRODUCTION

The posterior superior alveolar artery (PSAA) can be damaged during a number of surgical procedures and must be carefully analyzed during pre-assessment of the dental implantation site using CBCT.[1] Damage to this artery results in the potential risk of bleeding during the procedure which obscures the vision of the operator and may also lead to perforation of the Schneiderian membrane.[2] During placement of implants in the maxillary posterior region, the amount of residual bone present in this region plays a key role in its success. This may be affected by the maxillary sinus pneumatization, loss of alveolar bone due to tooth extraction, or vertical loss of residual bone. Therefore, careful pre-assessment of the amount of residual bone from the alveolar crest to the maxillary sinus should be considered in planning implantation in this region.[3] Cone-beam computed tomography (CBCT) aids in providing the best treatment plan by determining the location and characteristics of important anatomical landmarks before surgery.[4] Limited data are available to assess PSAA and residual bone together in posterior maxillae in Indian sub-populations. Hence, we aimed to investigate the information about the differences in radio morphometric measurements of PSAA and residual bone in the premolar and molar areas which may be useful for the rehabilitation of the maxillary posterior regions. The null hypothesis is that there is no statistical difference in the

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prevalence and location of PSAA and residual bone among different age groups, genders, and dentate status.

MATERIALS AND METHODS

This retrospective cross-sectional study was performed on 1000 CBCT volumes who had retrospectively undergone CBCT imaging at the Outpatient Department of Oral Medicine and Radiology for treatment purposes. The protocol ethics were approved by the research committee of the Institute, in accordance with the Helsinki Declaration. However, the final sample size was determined as 811 CBCT scans that met the inclusion criteria of the study and on the minimum radiologic prevalence of PSAA in the literature (i.e., 50%) which was necessary for calculating the maximum sample size, and a precision of $d = 0.05$ at a 95% level of confidence.

The study population was divided into three age groups: 10–30 years, 31–51 years, and 52–72 years. Comparisons were made age wise, gender wise, and dentate status, i.e., dentulous or partially edentulous. For Ethical Clearance was obtained from Institute of Dental Studies and Technologies Institutional Ethical Committee with Ref no IDST/IERBC/2017-20/25 dated 23/11/2017. A written consent was obtained from each patient to access their CBCT data for research.

CBCT Measurements

The cases were sampled randomly from the archive of existing CBCT volumes obtained from Kodak CS 9300 (Carestream Dental, Atlanta, USA) dental imaging system. Linear measurements were carried out to localize the mediolateral and vertical position of the posterior superior alveolar artery in postero-lateral wall of the maxillary sinus and its proximity to the floor of the 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 15s. Reformatting of the 3D reconstructions was created by using the axial CBCT scans on a 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 exclusion criteria comprised poor quality scans, scans with artifacts and pathological lesions disrupting normal sinus anatomy, and severe periodontal bone loss.

Each CBCT scan was oriented prior to the location of PSAA. The cross sections were obtained of the 1st and 2nd premolar and 1st and 2nd molar region in dentulous or edentulous maxillary scans and evaluated for the optimal visualization of the radiolucent PSAA in postero-lateral wall of the maxillary sinus. The relative position of PSAA to mediolateral wall of the maxillary sinus was determined as: (a) Type I: intrasinusal (b) Type II: intraosseous, and (c) Type III: superficial. [Figure 1] The location of PSAA was assessed in most caudal position of PSAA by using the following measurements: distance from PSAA to mesial wall of sinus (D1) [Figure 2], height from alveolar bone crest to floor of sinus (H2) [Figure 3], height from lower border of PSAA to alveolar bone crest (H1) [Figure 4].

The measurements were used to estimate the interobserver reliability. The resulting intra-class correlation coefficients ranged between 95 and 99%, indicating excellent inter-observer agreements.

Statistical analysis

Descriptive statistics and 95% confidence intervals (CI) were calculated. The data were analyzed using SPSS version 21.0 (IBM Corporation, New York, USA). Distribution of artery localization and radio morphometric 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

Overall, the PSAA canal was detected in 810 patients (99.87%) out of 811 approved subjects irrespective of age, gender, and dentate status. The prevalence of PSAA was seen maximum in 31–51 years (41.9%) and least in 52–72 years (23%). Of the 810 patients, 474 (58.4%) were males and 336 (41.4%) were females. There were 158 (19.5%) partially edentulous regions and 652 (80.4%) dentulous regions in which the canal was observed. Artery localization and tooth-wise distribution according to age, gender, and dentate status are described in Tables 1 and 2.

A detailed description of the distribution of PSAA and its various radiographic morphometric measurements according to age, gender, and dentate status are described in Tables 3-6.

The minimum artery diameter (0–1 mm) was seen maximum in the age group 31 to 51 years, in males and in dentate subjects, whereas the maximum artery diameter (>2.0 mm) was seen maximum in 31 to 51 years, in males and in dentate subjects, and the results were statistically significant ($P = 0.001$) [Table 3].

The mean height from lower border of PSAA to alveolar bone crest (H1) in both 10–30 and 31–51 years was found maximum at 1st premolar and minimum at 2nd molar region, whereas for 52–72 years, it was found maximum at 2nd premolar and minimum at 2nd molar region. In males, it was maximum at

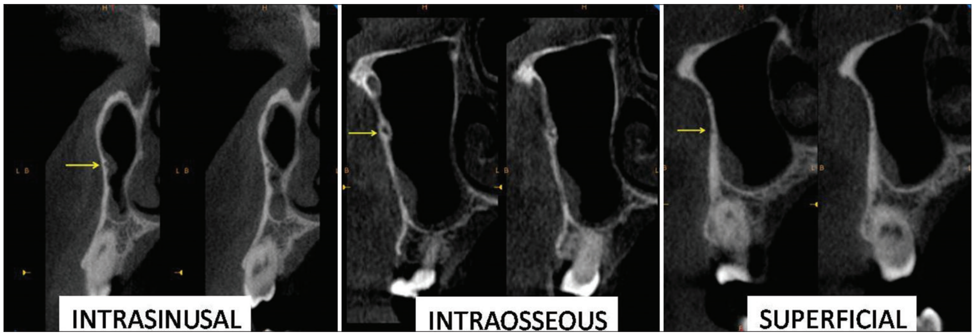

Figure 1: TYPE OF PSAA

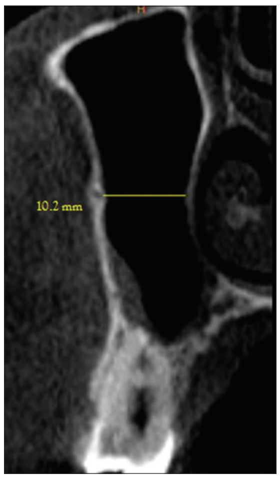

Figure 2: Distance from PSAA to medial wall of sinus (D1)

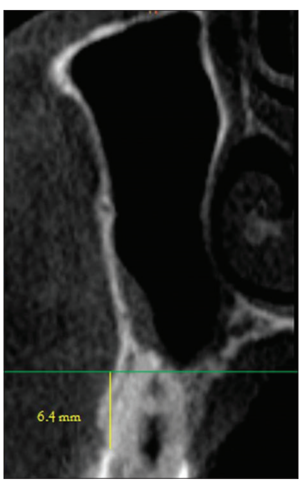

Figure 3: Height from alveolar crest to floor of sinus

1st premolar and minimum at 1st molar region, whereas for females, it was maximum at 1st premolar and minimum at 2nd molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 2nd molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant for the age group 10–30 years, gender wise and partially dentates ($P = 0.001$) [Table 4].

The mean height from alveolar bone crest to floor of sinus (H2) was found maximum at 1st premolar in all three age groups, whereas it was minimum at 2nd molar region for 10–30 years, at 1st molar region for 31–51 years, and at 2nd premolar region for 52–72 years, respectively. Irrespective of gender, it was maximum at 1st premolar and minimum at 1st molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 1st molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant ($P = 0.001$), except for males ($P = 0.029$). [Table 5]

The mean distance from PSAA to medial wall of sinus (D1) in all age groups was found minimum at 1st premolar region except for 52–72 years where it was at 2nd premolar region, whereas maximum was found at 2nd molar region. Irrespective of gender and dentate status, it was maximum at 2nd molar region and minimum at 1st premolar region and the results were statistically significant ($P = 0.001$), except for dentates ($P = 0.033$). [Table 6]

DISCUSSION

The challenges faced by surgeons during the rehabilitation of edentulous posterior maxilla depend on alveolar bone loss, post-extraction, or sinus pneumatization.[5] Common complications encountered during the surgical intervention in this region include perforation of the Schneiderian membrane and hemorrhage as a result of damage to PSAA bvgt65t. This may further lead to reduced visibility, postoperative hematoma, infection, and complete loss of graft.[5,6]

Therefore, a thorough knowledge of the blood supply of this region is of utmost important for the surgeon before planning any intervention. PSAA anastomoses with the infraorbital artery and supply the lateral wall of the maxillary sinus.[4]

The advent of CBCT and the vast array of advantages of using this advanced imaging modality have revolutionized the diagnosis and treatment planning in dentistry. In cases of dental rehabilitation of the posterior maxillary region, CBCT has proven to be a boon to surgeons and implantologists as it aids in radiological pre-assessment of the implant site in terms of one density assessment and other morphometric measurements of the implant site.[5,6]

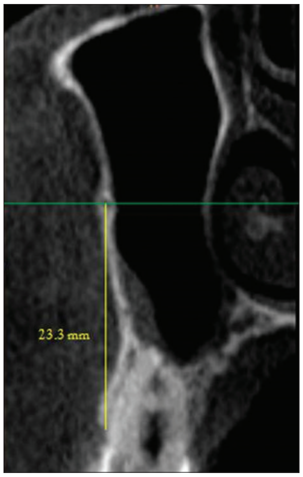

Figure 4: Height from lower of border PSAA to alveolar crest

The current study assessed gender-wise age-wise, tooth-wise differences in dentulous and edentulous patients in terms of localization, diameter of PSAA, height from lower border of PSAA to alveolar bone crest, height from lower border of PSAA to floor of sinus, distance from PSAA to medial wall of sinus, and height from alveolar bone crest to floor of sinus.

Further, the current study included 474 males and 336 females. Similar studies have been conducted in the past by Danesh-Sani *et al*.[5] and Tehranchi *et al*.[7] In the present study, PSAA was observed in dentate (n = 652) and partially edentulous

Table 1: Artery localization according to age, gender, and dentate status

		Absent	Type I	Type II	Type III	p value
		N (%)	N (%)	N (%)	N (%)	
Age	**10–30 years**	0	138 (49.6%)	140 (50.4%)	0	
	31–51 years	1 (0.3%)	74 (21.7%)	191 (56%)	75 (22%)	**0.0001***
	52–72 years	0	54 (28.1%)	108 (56.3%)	30 (15.6%)	
Gender	**Males**	0	164 (34.6%)	253 (53.4%)	57 (12%)	0.290
	Females	1 (0.3%)	102 (30.3%)	186 (55.2%)	48 (14.2%)	
Dentate status	**Dentate**	1 (0.2%)	234 (35.9%)	375 (57.4%)	43 (6.6%)	**0.0001***
	Partially Dentate	0	32 (20.3%)	64 (40.5%)	62 (39.2%)	

*P value significant at P<0.05, Chi-square test applied

Table 2: Tooth-wise distribution of different types of PSAA according to age, gender, and dental status

Variable		N (%)	PM1	PM2	M1	M2	p value
			N (%)	N (%)	N (%)		
Age	**10–30 years**	**Type I**	1 (0.7%)	74 (54.0%)	19 (13.2%)	44 (32.1%)	**0.001**
		Type II	57 (40.7%)	83 (59.3%)	0	0	
		Type III	0	0	0	0	
	31–51 years	**Type I**	26 (35.1%)	0	6 (8.1%)	42 (56.8%)	**0.001**
		Type II	47 (24.6%)	44 (23%)	74 (38.7%)	26 (13.6%)	
		Type III	0	27 (36%)	48 (64%)	0	
	52–72 years	**Type I**	0	29 (53.7%)	25 (46.3%)	0	**0.001**
		Type II	0	53 (49.1%)	30 (27.8%)	25 (23.1%)	
		Type III	0	0	30 (100%)	0	
Gender	**Males**	**Type I**	26 (15.9%)	103 (62.8%)	0	35 (21.3%)	**0.001**
		Type II	42 (16.6%)	145 (57.3%)	66 (26.1%)	0	
		Type III	0	27 (47.4%)	30 (52.6%)	0	
	Females	**Type I**	1 (1%)	0	50 (49%)	51 (50%)	**0.001**
		Type II	62 (33.3%)	35 (18.8%)	38 (20.4%)	51 (27.4%)	
		Type III	0	0	48 (100%)	0	
Dentate status	**Dentate**	**Type I**	27 (11.2%)	77 (33%)	44 (18.9%)	86 (36.9%)	**0.001**
		Type II	81 (21.6%)	149 (39.7%)	104 (27.7%)	41 (10.9%)	
		Type III	0	27 (62.8%)	16 (37.2%)	0	
	Partially dentate	**Type I**	0	26 (81.3%)	6 (18.8%)	0	**0.001**
		Type II	23 (35.9%)	31 (48.4%)	0	10 (15.6%)	
		Type III	0	0	62 (100%)	0	

*P value significant at P<0.05, Chi-square test applied

Table 3: Artery diameter distribution according to age, gender, and dental status

		0–1 mm	1–1.5 mm	1.5–2.0 mm	>2.0 mm	p value
		N (%)	N (%)	N (%)	N (%)	
Age	10–30 years	137 (49.5%)	98 (35.4%)	42 (15.2%)	0	0.001
	31–51 years	222 (65.1%)	118 (34.6%)	0	1 (0.3%)	
	52–72 years	55 (28.6%)	137 (71.4%)	0	0	
Gender	Males	218 (46%)	213 (44.9%)	42 (8.9%)	1 (0.2%)	0.001
	Females	196 (58.3%)	140 (41.7%)	0	0	
Dentate status	Dentate	301 (46.2%)	308 (47.2%)	42 (6.4%)	1 (0.2%)	0.001
	Partially Dentate	113 (71.5%)	45 (28.5%)	0	0	

**P* value significant at $P < 0.05$, Chi-square test applied

Table 4: Mean height from the lower border of PSAA to alveolar bone crest (H1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	28.05±2.81	24.72±3.63	20.8±0.0	16.2±5.24	0.001
	31–51 years	27.24±2.06	22.68±3.91	20.33±2.41	16.28±1.54	0.030
	52–72 years	-	21.17±1.99	17.34±2.43	17.5±0.0	0.014
Gender	Males	27.13±2.07	24.06±3.18	18.12±2.05	20.09±1.37	0.001
	Females	28.10±2.73	17.42±0.91	20.08±2.88	15.27±2.63	0.001
Dentate status	Dentate	27.26±2.57	24.21±3.34	19.12±3.19	16.30±3.21	0.030
	Partially dentate	29.20±0.0	19.31±1.99	19.63±0.98	19.0±0	0.001

**P* value significant at $P<0.05$, ANOVA applied

Table 5: Mean height from alveolar bone crest to floor of sinus (H2) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	23.57±2.19	15.08±3.84	13.3±0.0	11.20±3.32	0.001
	31–51 years	14.64±0.58	10.48±1.42	7.07±3.34	7.87±3.00	0.001
	52–72 years	14.63±3.79	6.31±0.62	9.40±0.0	10.27±4.64	0.001
Gender	Males	19.78±4.48	14.21±3.84	7.56±1.99	13.66±0.80	0.029
	Females	17.32±4.63	11.55±3.59	7.12±3.69	7.69±2.05	0.001
Dentate status	Dentate	19.26±4.94	14.63±3.81	8.44±2.37	9.74±2.67	0.001
	Partially dentate	15.5±0.0	10.72±2.52	4.57±2.97	2.60±0.0	0.001

**P* value significant at $P<0.05$, ANOVA applied

Table 6: Mean distance from PSAA to medial wall of sinus (D1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	3.52 ± 1.36	8.71 ± 2.54	10.50 ± 0.0	16.58 ± 2.01	0.001
	31–51 years	6.19 ± 0.08	10.96 ± 1.17	12.98 ± 1.54	17.18 ± 1.06	0.001
	52–72 years	-	10.61 ± 0.94	11.67 ± 1.46	17.0 ± 0.0	0.001
Gender	Males	4.29 ± 1.47	9.87 ± 1.83	12.02 ± 1.89	17.74 ± 0.99	0.001
	Females	5.79 ± 1.38	8.53 ± 3.94	12.49 ± 1.44	16.68 ± 1.39	0.001
Dentate status	Dentate	4.73 ± 1.65	9.49 ± 2.33	12.49 ± 1.51	16.79 ± 1.30	0.033
	Partially dentate	6.30 ± 0.0	10.75 ± 1.11	11.83 ± 1.91	19.0 ± 0.0	0.004

**P* value significant at $P < 0.05$, ANOVA applied

patients ($n = 158$). Similar studies were conducted in the past by Danesh-Sani *et al*.[5] and Ibrahim *et al*.[8]

The prevalence of PSAA in our study was 99.87% close to previously conducted cadaveric studies which was 100%.[9] In this study, age wise the most common course of PSAA was identified to be Type II (intraosseous) irrespective of age group but at different locations; at 2nd premolar region in 10–30 years ($n = 83$), at 1st molar region in 31–51 years ($n = 74$), and at 2nd premolar region in 52–72 years ($n = 53$). Gender wise it was again identified to be Type II (intraosseous) but at different locations; at 2nd premolar region in males ($n = 145$) and at 1st premolar region in females ($n = 62$). Dentate wise it was identified to be Type II (intraosseous) at 2nd premolar region in dentates ($n = 149$) and Type III (superficial) at 1st molar region in partially dentates ($n = 62$) and the results were statistically significant, respectively ($P = 0.001$) [Table 2]. Danesh-Sani *et al*.,[5] Tehranchi *et al*.,[7] Ibrahim *et al*.,[8] Chitsazi *et al*.,[9] and Ilguy *et al*.[10] Localization of the course of PSAA age wise, gender wise, and dentate wise in this study provides a better understanding PSAA in addition to other studies.

The diameter of PSAA has a direct impact on the extent and severity of hemorrhage. In this study, age wise the diameter of PSAA was found to be 0–1 mm in maximum 31–51 years (65.1%), 1–1.5 mm in maximum 52–72 years (71.4%), 1.5–2 mm in maximum 10–30 years (15.2%), and >2 mm in maximum 31–51 years (0.3%) and the results were found to be statistically significant ($P = 0.001$). However, Danesh-Sani *et al*.[5] and Rathod *et al*.[6] found no significant correlation between age and the size of the PSAA. Furthermore, different studies in the past have found the mean diameter of PSAA as 1.15 (±0.38) mm (Ibrahim *et al*.[8]); 1.52 (±0.47) mm (Kim *et al*.[11]); 1.3 (±0.5) mm (Güncü *et al*.[12]). These values are more than the results of the current study which could be attributable to ethnic differences and methodological differences. Gender-wise males had a larger diameter of PSAA with 0–1 mm found maximum in 46%, 1–1.5 mm found maximum in 44.9%, 1.5–2.0 mm found maximum in 8.9%, and >2 mm found maximum in 0.2% and the results were statistically significant ($P = 0.001$). The greater value in males could be attributed to larger skeletal features within males. Also, it has been reported by Ibrahim *et al*.[8] that genetic variance and racial differences could have an impact on these measurements. Dentate status wise it was more in dentate than partially dentate and 0–1 mm was maximum in 46.2%, 1–1.5 mm was maximum in 47.2%, 1.5–2.0 mm was maximum in 6.4%, and >2.0 mm was maximum in 0.2% Similar studies have been conducted in past by Kim *et al*.[11] where irrespective of age, gender, and dentate status almost no cases of PSAA diameter >2 mm were noted. Therefore, it can be assumed that the study population might have lowest risk of severe bleeding as a result of damage to the PSAA.

The mean distance between the lower border of PSAA to alveolar bone enables the clinician to assess length of implant planned or the extent of sinus elevation required to avoid risk of iatrogenic injury to PSAA. In the present study, irrespective of age it was shortest for 2nd molar and longest for 1st premolar except for 52–72 years where it was longest for 2nd premolar and the result was statistically significant ($P = 0.001$, $P = 0.030$, $P = 0.014$, respectively). Gender wise for males it was shortest for 1st molar and longest for 1st premolar for females it was shortest for 2nd molar and longest for 1st premolar and the result were statistically significant for both ($P = 0.001$). Dentate wise for dentate it was shortest for 2nd molar and longest for 1st premolar for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant ($P = 0.030$ and $P = 0.001$, respectively). These results were concurrent with other published studies by Chitsazi *et al*.,[9] Ilguy *et al*.,[10] Güncü *et al*.,[12] Watanabe *et al*.,[13] Kqiku *et al*.[14]

The mean height from the alveolar bone crest to floor of sinus was determined to assess the height of the alveolar ridge in the posterior maxilla which aids in the localization of PSSA. In the present study, for the age group 10–30 years it was shortest for 2nd molar and longest for 1st premolar, for 31–51 years it was shortest for 1st molar and longest for 1st premolar, for 52–72 years it was shortest for 2nd premolar and longest for 1st premolar and the result was statistically significant for all age groups ($P = 0.001$, respectively). Gender wise irrespective of gender it was shortest for 1st molar and longest for 1st premolar and males had a larger value with statistically significant results for both ($P = 0.029$, $P = 0.001$). Dentate wise for dentate it was shortest for 1st molar and longest for 1st premolar and for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant for both ($P = 0.001$, respectively). These results were similar to previous studies conducted by Kqiku *et al*.[14] and Apostolakis *et al*.,[15] where the values irrespective of age or gender or dentate status are minimum at 1st molar region increase slightly at 2nd molar region and are maximum at 1st premolar region. This may be attributed to the anatomy of the sinus which gets higher anteriorly. Also, PSAA's course in the anterior region moves superiorly to anastomose with the infraorbital artery. However, Shams *et al*.[16] did not have significant changes from the posterior side (8.0 mm) to the anterior side (4.0 mm). Also, Lee *et al*.,[17] found that the mean height of PSAA from floor of sinus was almost similar in the 2nd premolar, 1st molar, and 2nd molar regions.

The mean distance of PSAA to the medial wall of sinus is considered a more stable landmark for evaluation of the mediolateral position of PSAA as vertical dimensions are affected by sinus lift or ridge augmentation procedures. In the present study, irrespective of age it was shortest for 1st premolar, the values gradually increased and were maximum for 2nd molar except for 52–72 years where it was longest for 2nd molar and shortest for 2nd premolar. The results were statistically significant ($P = 0.001$, respectively). Gender wise irrespective of gender was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The results were statistically significant for both ($P = 0.001$, respectively). Dentate wise irrespective of dentate status was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The result was statistically significant for both ($P = 0.033$ and $P = 0.004$, respectively). In our study, the results showed that dentition status influenced the location of PSAA and partially dentate patients showed higher values. Pandharbale *et al*.[18] found similar results and suggested that it could be due to progressive atrophy of the alveolar bone. However, the results were not in accordance with those of Velasco-Torres *et al*.[19] and Hayek *et al*.[20] which showed that dentate had larger measurements.

CONCLUSIONS

The study supports that a careful evaluation of PSAA is imperative before surgical treatment of the maxillary sinus since it may complicate intraoperative bleeding and affect the integrity of the sinus and its membrane during the procedure. The intraosseous type was the most common variant of PSAA. Age-wise, gender-wise, and dentate wise the morphometric measurements of PSAA differ significantly in the study population. 3D imaging modality such as CBCT is useful to localize the PSAA as it provides finer details and should be recommended in clinical practices.

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Conflicts of interest
There are no conflicts of interest.

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