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Radiographic Evaluation Of The Posterior Superior Alveolar Artery Position In The Maxillary Sinus Using Cone Beam Computed Tomography: A Hospital-Based Study

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Abstract:
Background: *The maxillary sinuses have a close anatomical relationship with dental and maxillofacial structures, with the posterior superior alveolar artery (PSAA) serving as a major vascular contributor. The PSAA exhibits variable anatomical courses, most commonly intraosseous, and inadvertent injury during surgical procedures may result in complications such as excessive hemorrhage, sinus membrane perforation, and delayed healing. Cone beam computed tomography (CBCT) enables accurate visualization of the PSAA, facilitating precise assessment of its location and course. Therefore,the study aimed to evaluate the anatomical location and radiographic characteristics of the PSAA using previously acquired maxillary CBCT scans.*
Materials and Methods: *A retrospective analysis of maxillary CBCT scans from 215 patients was conducted. The anatomical course, diameter, and spatial relationships of the PSAA were assessed by measuring its distance from critical anatomical landmarks, including the alveolar crest/ridge, maxillary sinus floor, medial sinus wall, and the vertical height between the sinus floor and alveolar crest/ridge. Variations were analyzed according to age, gender, and dentition status. Additionally, the prevalence of maxillary sinus septa and their relationship with the PSAA were evaluated.*
Results: *Among the 215 participants, the PSAA most frequently exhibited an intraosseous course (approximately 52-55%), with no statistically significant differences related to gender, age, or dentition status. A unique finding of transosseous position was observed in 6.1% (15/215) of participants. Artery diameter was significantly greater in males and in individuals aged 50 59 years. Males also demonstrated a greater vertical distance between the PSAA and the maxillary sinus floor. Maxillary sinus septa were identified in 16.3% of cases, with no significant association with demographic variables or PSAA position.*
Conclusion: *CBCT allows precise evaluation of the PSAA's anatomical course, diameter, and spatial relationships, which is essential for minimizing intraoperative complications during maxillary sinus and posterior maxillary surgical procedures. Awareness of PSAA variations enhances surgical planning, safety, predictability, and clinical outcomes in dental and maxillofacial interventions.*
Keywords: *Posterior superior alveolar artery, maxillary sinus, cone-beam computed tomography, anatomical variations, maxillary sinus septa, surgical planning*

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I. Introduction

The maxillary sinus (MS) is a major anatomical structure within the maxilla. It lies in proximity to the roots of posterior maxillary teeth, making it highly relevant in dental and maxillofacial surgical practice. Anatomical variations such as sinus septa, mucosal thickening, and variations in adjacent neurovascular structures can influence surgical access and significantly increase the risk of intraoperative complications, particularly hemorrhage. For this reason, the maxillary sinus has long been recognized as a structure of critical clinical importance in interventions involving the posterior maxilla.[1-3]

The vascular supply of the maxillary sinus is mainly derived from branches of the maxillary artery, including the posterior superior alveolar artery (PSAA), infraorbital artery (IOA), and greater palatine artery.[3] Among these, the PSAA and IOA are primary contributors to the blood supply of the lateral sinus wall and the Schneiderian membrane. The anatomical trajectory of PSSA is variable; it commonly follows a straight course (78.1% in most cases), while a smaller proportion presents a U-shaped configuration (21.9%).[4]

Based on its spatial relationship with the lateral wall of the maxillary sinus, the PSAA has traditionally been classified into three patterns: intraosseous (69.6%), where it is embedded within the bony wall; intrasinusal (sub-membranous) (24.3%), where it runs beneath the Schneiderian membrane; and superficial, where it courses along the external cortical surface.[5] Recent literature has also described a transosseous variant, in which the artery traverses the lateral wall from the external cortex into the sinus cavity.[6] Among these patterns, the intraosseous course is most frequently observed, followed by the intrasinusal type, while the superficial course is least common.[7]

The PSAA forms clinically important anastomoses with the infraorbital artery, creating intraosseous and extraosseous vascular loops.[8] A notable manifestation of this anastomosis is the alveolar antral artery (AAA), which typically runs parallel to the sinus floor along the lateral wall of the maxillary sinus. The AAA often reaches its lowest position near the second premolar and first molar region and demonstrates its greatest diameter close to the first molar areas that are commonly involved during lateral window sinus augmentation procedures.[9]

Comprehensive preoperative knowledge of the maxillary sinus vasculature is essential to minimize complications such as Schneiderian membrane perforation, uncontrolled bleeding, and ischemia-related bone necrosis. Preservation of these vascular structures is fundamental for maintaining tissue vitality, promoting graft integration, and achieving successful wound healing through adequate neovascularization at augmented sites.

A thorough preoperative understanding of maxillary sinus vascular anatomy is essential to minimize complications such as Schneiderian membrane perforation, excessive bleeding, and ischemia-related bone necrosis. Preservation of these vascular structures is pivotal for maintaining tissue vitality, enhancing graft integration, and promoting effective wound healing through adequate neovascularization.[3] Accurate evaluation of PSAA position and lateral wall thickness is therefore critical when planning surgical procedures such as sinus floor elevation, Le Fort I osteotomy, orthodontic mini-screw placement, fracture osteosynthesis, and Caldwell-Luc operations.[8,10] Injury to the PSAA-IOA vascular network during sinus-related surgery may result in significant intraoperative bleeding, compromised visibility, extended operative time, and an increased likelihood of Schneiderian membrane perforation.[11]

Cone-beam computed tomography (CBCT) has emerged as the preferred imaging modality for preoperative assessment of the maxillary sinus, offering high-resolution three-dimensional visualization of both bony and vascular structures.[11,12] CBCT enables precise identification of the PSAA's presence, course, and diameter while maintaining radiation safety.[13] Despite its widespread use, population-based data on PSAA anatomical variations remain limited. Accordingly, the present study aims to evaluate the anatomical position and variations of the PSAA using CBCT, and to assess its relationship with key anatomical landmarks to support safer, more predictable surgical outcomes.

Aim of the study: To retrospectively assess the anatomical location and radiographic characteristics of the posterior superior alveolar artery (PSAA) using maxillary cone beam computed tomography (CBCT) scans.

II. Material And Methods

This retrospective hospital-based study was conducted in the Department of Oral Medicine and Radiology, SCB Dental College and Hospital, Cuttack, Odisha, India.

Study Design: Hospital-based, retrospective, cross-sectional study

Study Location: Department of Oral Medicine and Radiology, SCB Dental College and Hospital, Cuttack, Odisha, India,

Study Duration: January 2025 to December 2025

Sample size: 215 CBCT scans.

Sample size calculation: The sample size for the present study was determined using the prior study by Aamir Zahid Godil et al.[14] and the OpenEpi software. Applying the standard formula for prevalence studies with a 95% confidence level (Z=1.96), an estimated intraosseous PSAA prevalence of 84.2%, and a margin of error of 5%, the calculated minimum required sample size was 215 CBCT scans.

Subjects & selection method: Previously acquired CBCT scans from the Department of Oral Medicine and Radiology, SCB Dental College and Hospital, were retrospectively reviewed. A total of 1,000 CBCT images obtained for evaluation of the maxilla or maxillary sinus were screened, of which 215 scans with complete and suitable archived data were included in the study. Ethical approval was obtained from the Institutional Review Committee (IEC/SCBDCH/262/2024).

Inclusion criteria:
1. Previously acquired CBCT scans of the maxillary arch obtained with a field of view (FOV) of 11 × 8 cm or 11 × 13 cm.
2. CBCT scans demonstrating the PSSA
3. Scans showing any anatomical course of the PSAA, including intraosseous, sub-membranous (intrasinusal), superficial (extraosseous), or transosseous patterns.
4. Scans clearly depicting the inferior border of the PSAA, alveolar crest/ridge, bone height from the sinus floor to the ridge crest, and the medial wall of the maxillary sinus for accurate measurements.

Exclusion criteria:
1. Maxillary CBCT scan of a patient below 12 years of age.
2. Scans with poor image quality, motion artifacts, or beam hardening artifacts compromising visualization.
3. History of previous maxillary sinus surgery or grafting procedures.
4. Presence of sinusitis with partial or complete sinus opacification.
5. Maxillary sinus pathologies, including cysts or tumors.
6. Presence of sinonasal or nasal polyposis.
7. Patients with craniofacial anomalies affecting maxillary anatomy

Procedure methodology
- **CBCT imaging protocol and image analysis**:The study utilized a NewTom Giano cone-beam computed tomography (CBCT) system with standardized exposure parameters, including a field of view of 11 × 8 cm or 11 × 13 cm, a slice thickness of 300 microns, a scan time of 3.6 seconds, and an X-ray setting of 90 kVp and 10.8 mA. Archived CBCT DICOM files meeting the inclusion criteria were retrieved from the Department of Oral Medicine and Radiology, SCB Dental College and Hospital, anonymized, numbered, and analyzed in a blinded manner. Image visualization and measurements were performed on a medical-grade 19-inch EIZO LCD monitor using NewTom NNT analysis software (v10). Radiographic assessment included evaluation of PSAA prevalence and anatomical course, measurements of its spatial relationship to the alveolar crest/ridge, maxillary sinus floor, and medial wall, determination of PSAA diameter, assessment of alveolar bone height, and identification of maxillary sinus septa, with analyses stratified by age, gender, and dental status.
- **Anatomical background and radiological identification:** The posterior superior alveolar artery (PSAA), a branch of the maxillary artery, provides critical vascular supply to the maxillary sinus and adjacent structures. Cone beam computed tomography (CBCT) allows reliable radiological identification of the PSAA, which typically appears as a hypodense or radiolucent canal within or adjacent to the lateral wall of the maxillary sinus. Using NewTom NNT analysis software (version 10), CBCT images were assessed in axial, coronal, and sagittal planes with a 16-bit grayscale, and the right and left maxillary sinuses were evaluated independently for everyone.Radiological assessment involved sequential evaluation of coronal sections to identify the presence and anatomical course of the PSAA, characterized by either a circular or C-shaped corticated radiolucency. The artery was categorized as intraosseous or extraosseous, with extraosseous variants further classified as sub-membranous or superficial. Measurements included the diameter of the PSAA, distances from the inferior border of the artery to the medial sinus wall, alveolar crest or ridge, and maxillary sinus floor, with protocols adjusted for dentate and edentulous sites. Additionally, sinus septa were identified by systematically reviewing the sinus in anterior-posterior and superior-inferior directions. This comprehensive multiparametric CBCT assessment enabled detailed evaluation of PSAA morphology and its spatial relationships within the maxillary sinus.
- All data collection, storage, and analysis were performed exclusively by the principal investigator to ensure consistency, accuracy, and confidentiality of the collected information. Standardized protocols were followed throughout the study, and all research-specific procedures were conducted in accordance with internationally accepted methodological and ethical guidelines, thereby ensuring the validity and reliability of the study findings.

Statistical analysis

Data for all measured parameters were entered into Microsoft Excel and statistically analyzed using IBM SPSS Statistics for Windows, Version 20 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was applied to assess the normality of each variable's distribution, and the data were found to be normally distributed. Descriptive statistics were expressed as proportions, means, and standard deviations. As the data met the assumptions for normality, parametric statistical tests were employed for analysis. Intergroup comparisons of mean values were performed using appropriate parametric tests, and Pearson's correlation coefficient was used to evaluate associations between variables. A p-value of < 0.05 was considered statistically significant.

III. Result

The CBCT images of 215 healthy individuals (130 males and 85 females) were examined. The mean age of the participants was 38.73±13.48. About two-thirds of the participants (70; 32.6%) were <30 years of age, and the majority (155;71.1%) were dentate. **(Table 1)**

Table no 1: Characteristics of study participants

Characteristics	Male	Female	P value
N (%)	130 (60.5%)	85 (39.5%)	
Mean age (years)	38.73±13.48 years		
Age groups			
<30 years	42 (19.5%)	28 (13.0%)	0.011*
30-39 years	33 (15.3%)	15 (7.0%)	
40-49 years	16 (7.4%)	26 (12.1%)	
50-59 years	19 (8.8%)	9 (4.2%)	
60-69 years	20 (9.3%)	7 (3.3%)	
Dentition status			
Dentate	95 (44.2%)	60 (27.9%)	0.416
Edentate	35 (16.3%)	25 (11.6%)	
Chi-Square test; p<0.05*			

Overall, the intraosseous position of PSSA was the most common (113; 55.5%), followed by below membrane (73; 34.0%), superficial (16; 7.4%), and transosseous (5.1%), with no statistically significant association between gender and arterial position (p = 0.873). Considering the dentate status and position of PSSA, the intraosseous arterial position was most common in both genders, among dentate (80; 37.2%) and edentate (33; 15.3%) individuals, with no significant association between dentition status and arterial position (p=0.738) **(Table 2).**

Table 2: Distribution of artery localization according to age, gender, and dentition status

	Below membrane	Intraosseous	Superficial	Trans-osseous	P value
Gender					
Male	43 (20.0%)	71 (33.02%)	9 (4.2%)	7 (3.3%)	0.873
Female	30 (14.0%)	42 (19.5%)	7 (3.3%)	6 (2.8%)	
Age -groups					
<30 years	25 (11.6%)	39 (20.0%)	2 (0.9%)	4 (1.9%)	0.392
30-39 years	18 (8.4%)	22 (11.6%)	5 (2.3%)	3 (1.4%)	
40-49 years	15 (7.0%)	20 (10.7%)	4 (1.9%)	3 (1.4%)	
50-59 years	3 (1.4%)	18 (9.3%)	4 (1.9%)	2 (0.95%)	
60-69 years	12 (5.6%)	14 (7.0%)	1 (0.5%)	1 (0.5%)	
Dentition status					
Dentate	55 (25.6%)	80 (37.2%)	12 (5.6%)	8 (3.7%)	0.738
Edentate	18 (8.4%)	33 (15.3%)	4 (1.9%)	5 (2.3%)	
Chi-Square test; p<0.05*					

The radiographic parameters assessed were: (A) distance between the lower border of the artery and the alveolar crest, (B) bone height from the sinus floor to the ridge crest, (C) distance from the artery to the medial wall of the maxillary sinus, and (D) distance from the artery to the sinus floor. Most radiographic measurements were comparable between genders (p>0.05); however, the distance from the artery to the sinus floor was significantly greater in males (7.59 ± 3.47 mm) than in females (6.66 ± 2.49 mm; p=0.007), indicating a gender-related vertical variation. **(Table 3)**

When radiographic measurements were compared between dentate and edentate groups, no statistically significant differences observed for artery-alveolar crest distance (15.42 ± 3.47 vs 15.26 ± 2.76 mm; p=0.749), bone height (9.00 ± 2.91 vs 9.87 ± 4.40 mm; p=0.092), artery-medial wall distance (13.47 ± 3.13 vs 13.47 ± 3.03 mm; p=1.00), or artery-sinus floor distance (7.25 ± 3.16 vs 7.15 ± 3.13 mm; p=0.834). (Table 3). Comparing dentate and edentate subjects among genders for radiographic parameters showed a significantly greater bone height from the sinus floor to the ridge crest (10.83 ± 3.24 mm) compared to dentate females (8.80 ± 2.22 mm; p=0.001), while no such differences were observed in males (p>0.05).

Table 3: Comparison of mean radiographic measurements according to age , gender and dentition status

	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	Distance from the artery to the floor of the sinus
Gender#				
Male	15.63 ± 3.66	9.14 ± 3.80	13.39 ± 3.41	7.59 ± 3.47
Female	14.99 ± 2.60	9.39±2.60	13.60 ± 2.56	6.66 ± 2.49

P value	0.163	0.596	0.628	0.007*
Age-groups†				
<30 years	14.84±3.27	8.67±3.26	13.59±3.25	7.07±2.75
30-39 years	14.81±3.00	9.14±3.16	13.46±2.73	7.00±2.98
40-49 years	16.67±3.21	10.69±3.50	11.88±2.22	7.39±3.76
50-59 years	15.23±2.84	9.27±4.09	14.66±2.20	7.27±3.18
60-69 years	14.81±3.00	9.14±3.16	13.46±2.73	7.00±2.98
P value	0.059 (NS)	0.130	0.020*	0.943
Dentition status#				
Dentate	15.42±3.47	9.00±2.91	13.47±3.13	7.25±3.16
Edentate	15.26±2.76	9.87±4.40	13.47±3.03	7.15±3.13
P value	0.749	0.092	0.99	0.834
Student t test#; One -way ANOVA†; p<0.05*				

Table 4: Diameter of the posterior superior alveolar artery in relation to age , gender and dentition status

Parameters	Arterial diameter	P value
Gender#		
Male	1.13±0.36	0.007*
Female	1.00±0.32	
Age-groups†		
<30 years	1.05±0.32	0.003*
30-39 years	1.09±0.38	
40-49 years	0.94±0.20	
50-59 years	1.31±0.49	
60-69 years	1.11±0.28	
Dentition status#		
Dentate	1.08±0.35	0.176
Edentate	1.01±0.31	
Position of the artery†		
Below membrane	1.00±0.28	0.002*
Intraosseous	1.13±0.36	
Superficial	0.9±0.33	
Transosseous	1.27±0.41	
Student t test#; One-way ANOVA†; P<0.05*		

When arterial diameters were compared, males showed a significantly larger mean arterial diameter (1.13 ± 0.36 mm) than females (1.00 ± 0.32 mm), indicating a gender-related difference in arterial size (p=0.007). The artery diameter varied significantly across age categories (p=0.0003). Participants aged 50-59 years exhibited the largest mean artery diameter (1.31 ± 0.49 mm), while those in the 40-49 years group had the smallest (0.94 ± 0.20 mm). Dentate participants had a slightly higher mean septal diameter (1.08 ± 0.35 mm) than edentate participants (1.01 ± 0.31 mm), but the difference was not statistically significant (p=0.176). The diameter varied significantly with arterial position (p=0.002), with variations in artery diameter, with intraosseous arteries corresponding to a thicker artery **(Table 4)**

Table 5: Septal status with respect to age, gender, dentition status, and position of artery

Parameters	Presence, N(%)	Absence, N(%)	P value
Gender#			
Male	20 (9.3%)	110 (51.2%)	0.80
Female	15 (7.0%)	70 (32.6%)	
Age-groups†			
<30 years	14 (6.5%)	56 (26.0%)	0.188
30-39 years	7 (3.2%)	41 (19.1)	
40-49 years	2 (0.9%)	40 (18.6%)	
50-59 years	6 (2.79%)	22 (10.2%)	
60-69 years	6 (2.79%)	21 (9.8%)	
Dentition status#			
Dentate	24 (11.2%)	131 (60.9%)	0.76
Edentate	11 (5.1%)	49 (22.8%)	
Position of the artery†			
Below membrane	10 (4.6%)	63 (29.3%)	0.73
Intraosseous	19 (8.8%)	94 (43.7%)	
Superficial	4 (1.8%)	12 (5.6%)	
Transosseous	2 (0.9%)	11 (5.1%)	
Ch-square test#; Fisher–Freeman–Halton exact test†; p<0.05 (S)			

Septal presence was observed in 16.3% of participants, with no significant association between gender and septal occurrence (p=0.80), indicating that septal variation is independent of gender. No significant association was observed between age group and septal presence (p=0.80), indicating that septal presence is independent of age in this population. Among dentate participants, 24 (11.2%) had septal presence, compared to 11 edentate participants (5.1%). Statistical analysis revealed no significant association between dentition status and septal presence (p=0.76), indicating that the septal presence is independent of dentition status in this study population. Septal presence was observed across all arterial positions—most frequently with the intraosseous position (19 cases), followed by the below membrane (10 cases), superficial (4 cases), and transosseous positions (2 cases), but showed no statistically significant association with arterial position (p = 0.73), indicating that septal occurrence is independent of artery location. **(Table 5)**

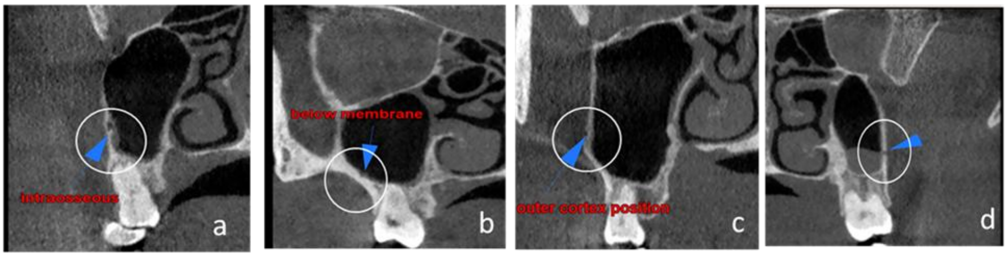

Figure no 1: Coronal CBCT images showing PSSA canal on lateral walls of maxillary sinus; (a) intraosseous, (b)intrasinusal, (c) superficial, (d) transosseous

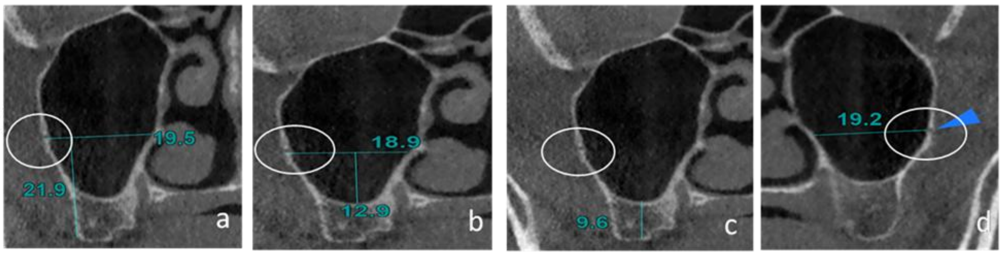

Figure no 2: Coronal CBCT images showing different radiographic distances in dentate group; (a) PSAA to alveolar crest; (b) PSAA to sinus floor; (c) Sinus floor to alverolar crest; (d) PSAA to sinus medial wall

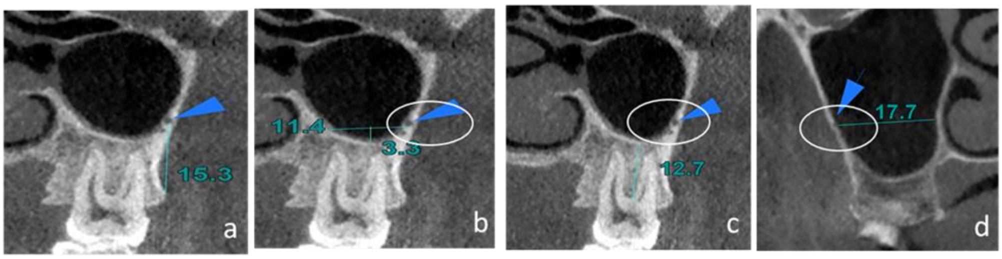

Figure no 3: Coronal CBCT images showing different radiographic distances in edentulous group; (a) PSAA to alveolar ridge (b) PSAA to sinus floor; (c) Sinus floor to alverolar ridge; (d) PSAA to sinus medial wall

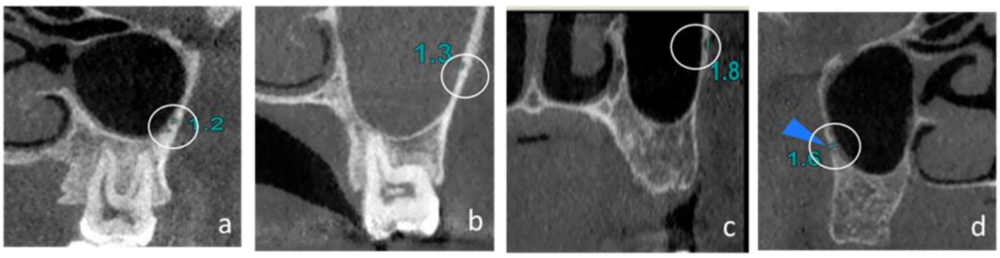

Figure no 4: Coronal CBCT image showing diameter of PSAA canal; a) intraosseous, (b)intrasinusal, (c) superficial, (d) transosseous

IV. Discussion

Surgical interventions involving the posterior maxilla demand a thorough understanding of regional anatomy, particularly the vascular structures associated with the maxillary sinus. The posterior superior alveolar artery (PSAA) is of paramount clinical significance owing to its consistent presence and variable anatomical course along the lateral sinus wall. Depending on its position, intraosseous, sub-membranous, or superficial, the

PSAA presents varying degrees of surgical risk, with intraosseous and sub-membranous locations being particularly vulnerable during osteotomy and membrane-elevation procedures.[3,15] Additional anatomical factors, including arterial diameter and the presence of maxillary sinus septa, further necessitate careful preoperative examination to avoid intraoperative complications.[3] CBCT-based assessment has emerged as the gold standard diagnostic modality, enabling accurate identification of risk zones, establishment of safe osteotomy margins, and individualized surgical planning, all of which are fundamental to preserving vascular integrity and enhancing procedural predictability.[2,3,15]

The present study reported a 100% PSAA prevalence, which, while consistent with cadaveric studies, is notably higher than CBCT-based reports by Anamali et al. (91%)[16], Ilgüy et al. (89.3%)[17], Tehranchi et al. (87%)[18], and Kurt et al. (78%)[19]. Considerably lower detection rates have been reported by Güncü et al. (64.5%)[4], Mardinger et al. (55%)[20], Elian et al. (53%)[21], Kim et al. (52%)[22], and Yang and Kye et al. (32.5%)[23]. This wide inter-study variability in prevalence is attributable to differences in CBCT acquisition parameters, including voxel size, image resolution, and contrast, as well as variations in sample size and racial or ethnic composition of study populations. Males had a higher prevalence (60.5%) than females (39.5%), consistent with Park et al.[15] (males 66.7%, females 50%) and Kim et al.[22] (males 64%, females 40%). Conversely, Waingade et al.[3] reported a contrasting female predominance (93.47% females vs. 87.15% males). The present study further identified a male predominance in younger age groups and relative female predominance among middle-aged participants, a pattern explainable by sexual dimorphism in maxillary bone morphology and vascular caliber, with males typically exhibiting greater bone thickness and larger vessel diameters, enhancing PSAA detectability on CBCT.[15,22] Age-related hormonal changes in females may additionally influence bone remodeling and arterial visibility across age groups.[24] The PSAA was more frequently identified in dentate than in edentulous regions, consistent with Ilgüy et al.[17], as preserved alveolar bone height in dentate patients favors retention of the artery within the lateral bony wall, whereas ridge resorption in edentulous areas tends to displace it toward sub-membranous or superficial positions.

The intraosseous PSAA course was observed in 55.5% of cases, aligning with the reported prevalence range of 47-73.2% in prior literature. The frequencies of sub-membranous (34.0%) and superficial (7.4%) positions were similarly consistent with Rathod et al.[8], Waingade et al.[3], and Elian et al.[21] A notable contrast was observed with Tehranchi et al.,[18] who reported equal intraosseous and sub-membranous frequencies of 47% each. A transosseous course was identified in 5.1% of cases, in line with the reported range of 1-6.6%, and represents a rare but clinically relevant anatomical variant. The predominance of intraosseous positioning across studies may reflect the higher proportion of dentate individuals with preserved alveolar bone, while edentulism and advanced resorption tend to shift the artery superficially, as consistently reported by Rathod et al.[8] and Waingade et al.[3] Importantly, the association between arterial position and both age and gender were not statistically significant, indicating that arterial positional variation is independent of these demographic variables. No significant association was found between dentition status and arterial position either, consistent with Duruel et al.[12], though intraosseous positioning remained the most common in both dentate (37.2%) and edentulous (15.3%) subgroups.

The radiographic parameters and gender

Gender-wise analysis of four PSAA-related radiographic parameters, PSAA-alveolar crest distance (PSAA-AC/AR), PSAA-sinus floor distance, PSAA-medial wall distance (PSAA-MW), and sinus floor–alveolar crest bone height, revealed no statistically significant differences for most parameters. The sole exception was the PSAA-sinus floor distance, which was significantly greater in males than in females. This finding is analytically consistent with Fayek et al.[25] and Gulec et al.[26], who similarly identified a greater PSAA-sinus floor distance in males while reporting no significant gender differences in other PSAA measurements, with the disparity attributed to larger maxillofacial skeletal dimensions and greater vertical sinus development in males, as proposed by Tassoker et al.[5] This gender-related anatomical variation holds direct clinical relevance during lateral window sinus augmentation, where precise arterial localization is essential to minimize intraoperative hemorrhage risk.[8,27]

The mean PSAA–alveolar crest distance was 15.31 ± 3.13 mm, consistent with Chitsazi et al.[28] and Kurt et al.[19], and within the safe lateral window margin of 14-15 mm recommended by studies in the literature.[11,20,29,30] This finding suggests that the risk of inadvertent arterial injury during window preparation is minimal in the majority of cases. However, the present value was lower than those reported by Godil et al.[14] (17.37 ± 3.94 mm) and Tehranchi et al. (16.7 ± 1.63 mm)[18], with discrepancies attributable to population variability, alveolar ridge atrophy, degree of maxillary pneumatization, and differences in imaging methodology.[27] Importantly, the PSAA-alveolar crest distance progressively decreased following tooth loss, most markedly in fully edentulous patients, likely due to concurrent biological processes of alveolar bone resorption and sinus pneumatization post-extraction. Sinus pneumatization progresses from birth until approximately 20 years of age, after which the sinus stabilizes anatomically.[11] No significant gender difference was identified for this parameter, consistent with Tehranchi et al.[18], and Pandharbale et al.[31] In contrast, Velasco-Torres et al.[32] reported a significant gender difference, a discrepancy likely attributable to population heterogeneity and observer variability.[6] As alveolar crest-based measurements are susceptible to confounding by ridge atrophy, the sinus floor represents a more reliable and reproducible reference point for PSAA localization, as advocated by a few studies in the literature.[11,23,34]

The mean PSAA-sinus floor distance of 7.125 ± 2.98 mm closely approximates Park et al.'s[15] reported range of 7.71-8.01 mm, who recommended a minimum lateral window height of 8 mm to permit adequate visualization and instrumentation. The present findings suggest that restricting lateral window height to approximately 7 mm substantially reduces the risk of arterial injury, corroborating Radmand et al.[11] recommendations. The contrasting higher mean value of 9.69 ± 2.92 mm reported by Godil et al.[14] likely reflects population-specific differences in residual ridge height, maxillary atrophy severity, and imaging protocols. The mean PSAA-medial wall distance was 13.39 ± 3.41 mm in males and 13.60 ± 2.56 mm in females, comparable to Ilgüy et al.[17] values of 13.92 ± 2.84 mm (dentate) and 13.00 ± 2.32 mm (edentulous), supporting the medial sinus wall as a stable anatomical landmark for medio-lateral arterial localization.[14,17] Divergence from Pandharbale et al.[31] is attributable to population variability and methodological differences.[10,14] Mean sinus floor-alveolar crest bone height was 9.14 ± 3.80 mm in males and 9.39 ± 2.60 mm in females, consistent with Godil et al.[14], providing a critical adjunct for implant length selection in posterior edentulous regions.

The radiographic parameters and age

Most radiographic measurements, i.e., PSAA-alveolar crest distance, sinus floor-ridge crest bone height, and PSAA-sinus floor distance were not significantly influenced by age, reflecting the relative structural stability of posterior maxillary osseous and vascular anatomy across adulthood. This observation is analytically consistent with Danesh-Sani et al.[7] and other CBCT analyses, which demonstrate no significant correlation between age and PSAA vertical distances.[31] The notable exception was the PSAA-medial wall distance, which varied significantly with age, recording the lowest mean in the 50-59 years group and the highest in the 60-69 years group. This non-linear pattern suggests age-related medial arterial displacement within the sinus wall, possibly driven by progressive sinus remodeling and bone resorption with advancing age[24], a finding corroborated by Ilgüy et al.[17], who similarly reported shorter PSAA-MW distances in older patients. Clinically, while age is not a reliable universal predictor of posterior maxillary radiographic dimensions, selective age-related changes in arterial medial-wall positioning warrant particular attention during surgical planning in older patients.[24]

The radiographic parameters and dentition status

No statistically significant differences were identified across all four PSAA-related radiographic parameters between dentate and edentulous groups. The mean PSAA–alveolar crest distance was 15.42 ± 3.47 mm (dentate) and 15.26 ± 2.76 mm (edentulous), consistent with Waingade et al.[3], while the PSAA-MW distance was 13.47 ± 3.13 mm in both groups, in accordance with Elian et al.[21] and Waingade et al.[3] The relative stability of PSAA anatomical positioning, irrespective of dental status, despite alveolar resorption and post-extraction sinus pneumatization, has been consistently corroborated by studies in the literature.[4,17,20] This collectively supports the conclusion that dentition status alone cannot reliably predict PSAA position, reinforcing the clinical necessity of individualized preoperative CBCT evaluation. A clinically significant exception was identified in female participants, in which bone height from the ridge crest to the sinus floor was significantly greater in edentulous than in dentate females, suggesting a gender-specific response to tooth loss, potentially reflecting differential rates of sinus pneumatization or alveolar remodeling following extraction in females.

Artery diameter and gender, age, and dentition status

The mean PSAA diameter was 1.13 ± 0.36 mm in males and 1.00 ± 0.32 mm in females, consistent with previous studies.[3,7,22,28] The larger diameters observed in males corroborate Rathod et al.[8] and Danesh-Sani et al.[7], with the clinical implication that male patients carry a heightened intraoperative hemorrhage risk during lateral window sinus augmentation, warranting heightened surgical caution.[11] Notably, Mardinger et al.[20] found no significant gender-based diameter difference, a discrepancy attributable to population and methodological heterogeneity.[3] Arterial diameter showed a positive association with age in the present study, consistent with Mardinger et al.[20] and Khojastepour et al.[24], although other studies reported no such relationships[3,4,35], reflecting inter-study variability in population characteristics and imaging protocols. Dentition status did not significantly influence PSAA diameter, consistent with the established principle that intrinsic arterial caliber is maintained regardless of alveolar bone status[4,17,20] as tooth loss and sinus pneumatization predominantly affect surrounding osseous structures rather than the artery itself. A significant association between arterial position and diameter was established, with transosseous arteries exhibiting the greatest mean diameter, followed by intraosseous, below-membrane, and superficial positions, a finding analytically consistent with similar studies in literature[4,7,20] who demonstrated that arteries coursing deeper within bone are structurally more robust and therefore pose substantially greater hemorrhagic risk when inadvertently injured during surgery.

Prevalence of maxillary sinus septa and relation with PSAA position

Sinus septa were identified in 35 participants (16.3%), consistent with the established prevalence range of 13-35%[36,37] and the broader documented range of 16-69%.[3,38,39] The higher prevalences of 24.8-26% reported by Güncü et al. [4] and Chitsazi et al.[28] likely reflect differences in study design, population demographics, and imaging modality. No significant association was found between septal prevalence and gender, age, or dentition status, consistent with Orhan et al.[38] and Krennmair et al[36]. While Shen et al. [40] reported a male predilection, the overall evidence, including Neugebauer et al.[41]and Waingade et al.[3], remains inconclusive regarding the gender-septal relationship. Developmentally, Underwood et al.[42] described sinus septa as remnants of irregular pneumatization following tooth extraction and classified them as normal anatomical variants. From a clinical perspective, sinus septa substantially increase the technical difficulty of sinus lift procedures and are strongly associated with Schneiderian membrane perforation, the most common intraoperative complication, with an incidence of 11-56%, a correlation consistently reported in the literature.[3,7,35,39] No significant association was identified between arterial position and septal presence, consistent with Gulec et al.[26], indicating that septal occurrence is independent of PSAA location. Collectively, these findings reinforce the clinical imperative of routine preoperative CBCT assessment irrespective of gender, age, or dentition status, to accurately identify and localize sinus septa and ensure safe, predictable posterior maxillary surgical outcomes.

Strengths and limitations

This study employed cone-beam computed tomography (CBCT) to detect the posterior superior alveolar artery (PSAA), demonstrating high reproducibility and cost-effectiveness. CBCT may therefore be recommended as a dose-sparing alternative to conventional computed tomography for maxillofacial imaging. However, the study has certain limitations, including a relatively small sample size, unequal distribution between dentate and edentulous participants, and nonuniform representation across age and gender groups. Consequently, further studies with larger and more evenly distributed samples are warranted, incorporating comparisons between dentate and edentulous patients across different age groups while accounting for potential confounding factors.

V. Conclusion

This CBCT-based retrospective study of 215 scans comprehensively characterized the PSAA along the posterior maxillary lateral wall. The intraosseous course predominated, with a clinically significant transosseous variant identified, though arterial position was independent of gender, age, and dentition status. Males demonstrated significantly greater PSAA–sinus floor distance and larger arterial diameters, conferring a heightened hemorrhagic risk during lateral window sinus augmentation. Arterial diameter increased with age and correlated with deeper osseous positioning, whereas dentition status did not affect arterial caliber. Sinus septa prevalence was 16.3%, independent of all demographic variables. These findings collectively reinforce the indispensability of individualized preoperative CBCT assessment for safe posterior maxillary surgery.

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