Original paper

Anatomical localization of posterior superior alveolar artery: A retrospective study by cone-beam computed tomography

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Abstract

Background. Familiarity with the anatomy of the arteries in the sinus wall is essential to prevent the perforation of the sinus membrane and bleeding during dental implant surgery.

Objectives. The aim of the study was to evaluate the anatomical position of the posterior superior alveolar artery (PSAA), using cone-beam computed tomography (CBCT).

Material and methods. A total of 245 CBCT scans met the eligibility criteria for this cross-sectional study. The vertical distance from the lower border of the artery to the lower border of the sinus floor, the diameter of the artery, and the type of artery (intrasinusoidal, intraosseous or superficial) in the first and second premolar and molar regions were measured. The data was analyzed with the t tests, the one-way analysis of variance (ANOVA) and the χ^2 tests.

Results. The maxillary PSAA was recognized in 187 (76.3%) scans. The mean distance between the artery and the floor of the sinus was 6.87 ±3.68 mm. The mean diameter of the artery was 1.37 ±0.61 mm. The greatest mean diameter of the artery was observed in the second premolar region, and the smallest in the first molar region. As many as 63.6% of the arteries were intraosseous, 28.9% intrasinusoidal, and 7.5% superficial.

Conclusions. Due to the high prevalence of the intraosseous type, in most cases of sinus lift surgery there is an increased possibility of PSAA damage. As the largest diameter of the artery was observed in the second premolar region, the possibility of severe bleeding during sinus lift surgery in this area is increased. The average distance between the artery and the floor of the sinus was approx. 7 mm. Consequently, it is recommended that the lower border of the sinus access window should be as high as 7 mm to the floor of the sinus.

Keywords: CBCT, cone-beam computed tomography, maxillary sinus, posterior superior alveolar artery, PSAA

Introduction

Sufficient alveolar bone in terms of width and length is essential for the successful insertion of dental implants. However, the vertical dimension of the bone is reduced in the posterior region of the maxilla due to the pneumatization of the maxillary sinus following tooth loss, making implant placement difficult.[1,2]

The maxillary sinus is pyramidal in shape and retains its overall size when the posterior teeth are in use. However, it expands with age, especially when the posterior teeth are lost. In this case, the sinus cavity expands in both the lower and upper directions. The maxillary sinus cavity is lined with respiratory epithelium, beneath which the connective tissue is immediately adjacent to the bony walls covered with the periosteum. This complex of structures is known as the Schneiderian membrane. Most blood supply to the maxillary sinus and the Schneiderian membrane is provided by the posterior superior alveolar artery (PSAA) and the infraorbital artery (IOA), which are branches of the maxillary artery.[3,4] The maxillary artery itself is a branch of the external carotid artery, which divides into 5 branches in the pterygopalatine fossa.

The PSAA and IOA have intraosseous and extraosseous branches that anastomose about 19 mm from the alveolar bone crest in the anterior-lateral antral bone wall.[3–6] The PSAA travels to the end of the maxillary tuberosity to reach the bone and the periosteum. The location of this artery is usually determined between the lower and middle third of the lateral wall of the sinus.[7] With the development of implant treatment, Tatum and then Boyne introduced a technique called sinus floor elevation, which provides the required bone height to correctly place implants.[1,2]

The most common complication of dental implant insertion in the maxilla is the perforation of the sinus membrane.[8] Bleeding during sinus lift surgery is the second most common complication after the perforation of the Schneiderian membrane, mostly caused by an injury to PSAA.[3] This complication prolongs the surgical process due to reduced vision followed by reduced patient cooperation, and a higher risk of inflammation, pain and infection after surgery. Other reported complications include postoperative bleeding, nose bleeds, nasal congestion, hematoma, empyema, and sinus infection. The adequate pre-surgical and intra-surgical localization of the arteries, particularly of the PSAA, can prevent the injury to these structures and make the surgery less complex.[5,9]

Cone-beam computed tomography (CBCT) is the current diagnostic imaging technique used for the planning of most kinds of dental treatment. In recent years, it has reached extremely high resolution levels. However, this procedure is always to the detriment of the patient, who receives a dose of ionizing radiation. On the other hand, these radiation doses are becoming lower thanks to technological advancements.[10,11] There is increasing evidence that the use of magnetic resonance imaging (MRI) can bring the same effects as CBCT, but with the absence of ionizing radiation, which allows more frequent examinations without biological damage. For now, there is limited availability of this type of imaging for surgical use in dentistry, but in the near future, it may represent an excellent technique for this purpose.[12,13] In the implant treatment plan, CBCT provides valuable information about the width and height of the alveolar bone, bone morphology, pathologies, and important anatomical landmarks.[6,7]

Considering the necessity of familiarity with the anatomy of these arteries and genetic variations in different populations, the present study aimed to evaluate the anatomical position of PSAA by means of using CBCT in a defined group of patients in Qazvin, Iran.

Material and methods

In this descriptive, analytical cross-sectional study, all the maxillary CBCT scans from the archives of the Maxillofacial Radiology Clinic in Qazvin, Iran, were examined by the enumeration method and after reviewing the inclusion criteria, 537 cases were found to be eligible for the study. All patients had signed an informed consent form and gave permission to use their tomographic data anonymously for scientific purposes.

The exclusion criteria were: poor quality of CBCT scans; the presence of sinus pathologies; jaw fractures; the presence of dental implants in the maxillary sinus area; sinus grafts; complete edentulism (bilateral maxilla–mandible in the posterior area), no sinus observations, and duplex incontinence.

The images were taken with the ProMax® 3D imaging unit (Planmeca, Helsinki, Finland) with a voxel size of 0.3 × 0.3 mm^2. In each case, each quadrant was examined separately. In the presence of the teeth, the location of PSAA (in the area of first and second molars as well as first and second premolars) was determined based on the long axis of the teeth.[14] In the edentulous areas, the approximate location of the teeth was determined by the opposite or adjacent teeth, and the long axis of the alveolar crest was drawn.

All measurements were performed separately by 2 trained individuals (an oral radiologist and an implantologist) and the correlation coefficient was 93.6%.

Irradiation conditions, including kVp, mA and time, were adjusted based on the patient size. The observers examined the CBCT images in the sagittal plane by using the Romexis® Viewer, v. 3.8.3 (Planmeca, Helsinki, Finland). In all cases, the vertical distance from the lower border of the artery to the lower border of the sinus floor (Fig. 1), the diameter of the artery (Fig. 2) and the type of artery (intrasinusoidal, intraosseous or superficial) in the first and second premolar and molar areas (Fig. 3) were examined and categorized based on age and gender.

Fig. 1. Measurement of the vertical distance from the lower border of the artery to the lower border of the sinus floor

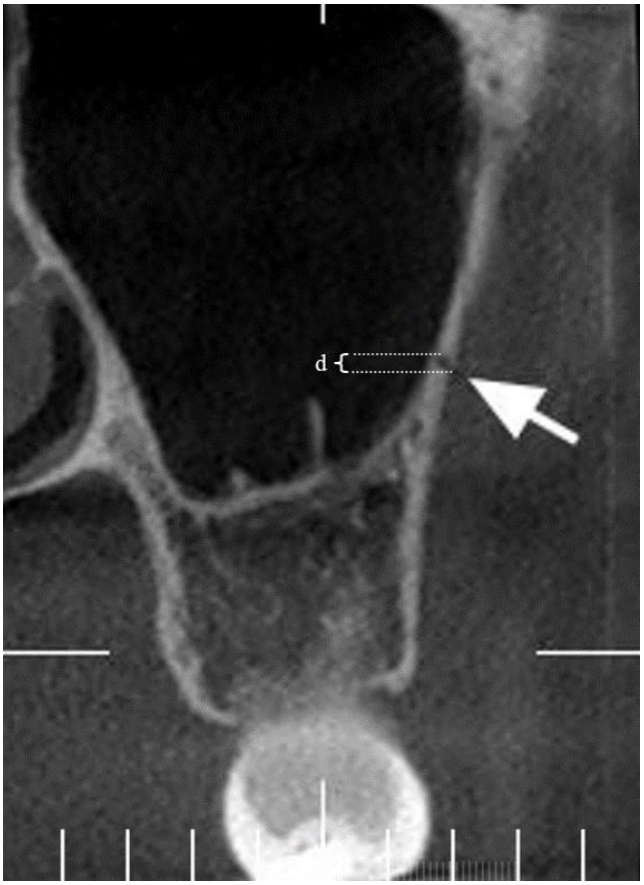

Fig. 2. Measurement of the diameter of the artery

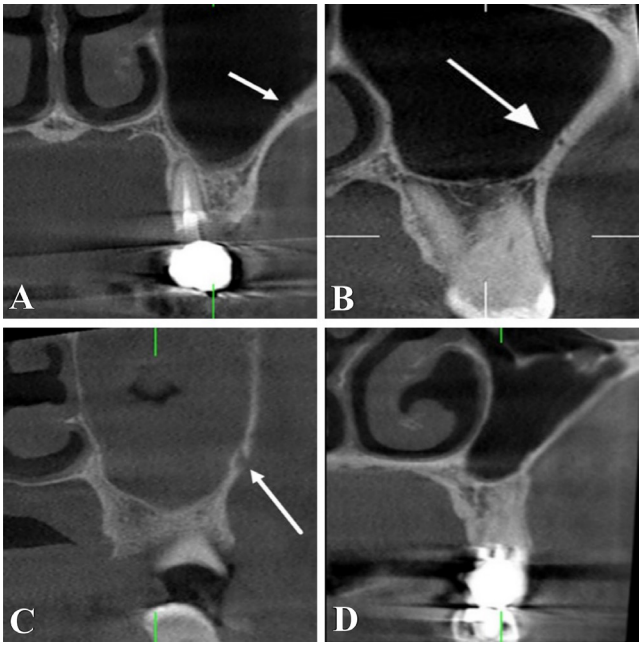

Fig. 3. Type of artery
A – intrasinusoidal; B – intraosseous; C – superficial.

Statistical analysis

The data was analyzed with the IBM SPSS Statistics for Windows software, v. 21.0 (IBM Corp., Armonk, USA). The Kolmogorov–Smirnov test was used to evaluate the normality of data distribution. Descriptive results were calculated by frequency, mean (*M*) and standard deviation (*SD*), based on the type of variable. The independent *t* tests and the one-way analysis of variance (ANOVA) were used to investigate the relationships between the quantitative variables. The χ^2 tests were used to investigate the relationships between qualitative variables. The level of significance was set at $p < 0.05$.

Results

A total of 245 CBCT scans from 80 males (32.7%) and 165 females (67.3%) met the eligibility criteria of this study. The patients were aged 17–68 years, with an average age of 38.46 years. Among the 245 samples, PSAA was recognized in 187 cases (76.3%), but not observed in 58 cases (23.7%).

The χ^2 tests were used to explore the relationships between age and the visibility of PSAA. There was a significant relationship between the arterial observation and age ($p = 0.040$). The highest rate of observation was noted in the age range of 40–50 years, and the lowest rate at the age of <30 years (Table 1).

The PSAA was observed in 77.5% of men and 75.8% of women. There was no significant difference between the rate of observation and gender ($p = 0.400$).

Table 1. Relationship between the rate of observation of the posterior superior alveolar artery (PSAA) and age

Age [years]	Rate of observation *n* (%)		*p*-value
	visible	not visible	
<30	40 (63.5)	23 (38.5)	0.040*
30–39	66 (79.5)	17 (20.5)	
40–50	47 (82.5)	10 (17.5)	
>50	34 (81.0)	8 (19.0)	

* statistically significant.

The mean distance from the artery to the sinus floor was 6.87 ±3.68 mm. The longest distance from the artery to the floor of the sinus was in the second molar region, and the shortest in the second premolar region. The mean distances obtained in the areas of second premolars, first premolars, second molars, and first molars were 6.52 mm, 6.58 mm, 7.43 mm, and 6.85 mm, respectively. There were no significant differences in the distances to the sinus floor in the different areas (p = 0.790).

In male patients, the mean distance from the artery to the floor of the sinus was 6.49 mm, and in females it was 7.2 mm. No significant difference was found between males and females in this respect (p = 0.950). The mean distances from the artery to the sinus floor in age groups <30 years, 30–39 years, 40–50 years, and >50 years were 6.44 mm, 6.01 mm, 7.64 mm, and 6.94 mm, respectively. The relationship between the distance and age was not significant (p = 0.800).

The mean diameter of the artery was 1.37 ±0.61 mm. The largest mean diameter of the artery was observed in the second premolar region, and the smallest in the first molar region. No significant relationships were found between the artery diameter and the dental area (p = 0.800) or age (p = 0.630) (Table 2). In addition, the difference between the mean artery diameter in men (0.35 ±1.33 mm) and women (0.41 ±1.49 mm) was not significant (p = 0.070).

The PSAA was intraosseous in 63.6% of cases, intrasinusoidal in 28.9% of cases, and superficial in 7.5% of cases.

Table 2. Differences in the diameter of the posterior superior alveolar artery (PSAA) between different dental areas and age groups

Variable		PSAA diameter [mm]	*p*-value
Dental area	second premolar	1.44 ±0.39	0.800
	first premolar	1.37 ±0.59	
	second molar	1.37 ±0.88	
	first molar	1.25 ±0.40	
Age [years]	<30	1.40 ±0.20	0.630
	30–39	1.40 ±0.41	
	40–50	1.39 ±0.44	
	>50	1.28 ±0.30	

Data presented as mean ± standard deviation (*M* ±*SD*).

The highest distribution was related to the intraosseous type, and the lowest to the superficial type. No significant differences were found between the artery type and age or gender (p > 0.05) (Table 3).

Table 3. Distribution of the posterior superior alveolar artery (PSAA) type according to age and gender

Variable		PSAA type	Percentage [%]	*p*-value
Age [years]	<30	intraosseous	65.0	>0.05
		intrasinusoidal	25.0	
		superficial	10.0	
	30–39	intraosseous	60.6	
		intrasinusoidal	31.8	
		superficial	7.6	
	40–50	intraosseous	61.7	
		intrasinusoidal	36.2	
		superficial	2.1	
	>50	intraosseous	70.6	
		intrasinusoidal	17.6	
		superficial	11.8	
Gender	male	intraosseous	66.1	>0.05
		intrasinusoidal	27.4	
		superficial	6.50	
	female	intraosseous	62.4	
		intrasinusoidal	29.6	
		superficial	8.0	

Discussion

Bleeding from PSAA is the second most common complication during sinus lift surgery. The occurrence of this complication can restrict vision and access during surgery, leading to the perforation of the sinus membrane or the inadequate removal of the Schneiderian membrane.

The percentage of arterial observation with the use of CBCT in the current study was 76.3%, which agrees with the studies of Chitsazi et al. (71.0%)[15] and Khojastehpour et al. (80.6%).[16] Rosano et al. reported 47% for this rate,[17] Güncü et al. 64.5%,[18] Mardinger et al. 55.0%,[19] Ilgüy et al. 89.3%,[20] and Anamali et al. 93.9%.[21] Regarding these differences in the percentage of observation, several factors can be considered. First, some of these studies used CT to assess the arteries, and it is known that CBCT provides more accurate linear assessment than CT. Also, the observer's skill in examining radiographs could be considered a contributing factor. In the present study, 2 observers were involved for more accuracy. In addition, some of these studies used printed CBCT images for the measurements. Thus, it was not possible to change the magnification and contrast for more accurate assessment. Finally, the most important factor related to these discrepancies may be racial differences.

In the present study, a significant relationship was noted between the rate of the arterial observation and age. The highest rate of observation was seen in the age range of 40– 50 years, and the lowest at the age <30 years. This indicates that aging increases the likelihood of artery recognition on radiographs, which may be attributed to an increased probability of the presence of osteoporosis in the sinus walls with aging.

There was no significant difference between the arterial observation rate and gender, which is consistent with Khojastehpour et al.[16] and Ilgüy et al,[20] but in contrast to Kim et al.[22]

There are 3 types of PSAA: intraosseous; intrasinusoidal; and superficial. In this study, the prevalence of intraosseous, intrasinusoidal and superficial arteries was 63.6%, 28.9% and 7.5%, respectively. It should be noted that in all age and gender groups, the most common type was an intraosseous artery, and the least common the superficial type. These findings agree with the observations of Danesh-Sani et al.,[23] Ilgüy et al.,[20] Güncü et al.,[18] and Chitsazi et al.[15]

The alveolar ridge undergoes changes after tooth extraction, which mainly depend on the anatomy and quality of the bone. From the age of 20, the maxillary sinus reaches its final size, about 5 mm below the nasal cavity. The protruding dental roots are associated with a thin cortex in the apex region and after the extraction of the root, a great deal of resorption occurs in the buccal apical region. However, the reduction of the ridge dimensions is particularly due to the trauma caused by tooth extraction rather than the pneumatization of the maxillary sinus.[15]

In most studies, the distance between the artery to the apex of the alveolar ridge has been evaluated, but the sinus floor is a more suitable starting point for this measurement, as it changes less than the alveolar ridge. Therefore, in the present study, the distance from the artery to the sinus floor in the areas of first and second molars and premolars was evaluated.

In the current study, the mean distance from the artery to the sinus floor was 6.87 ±3.68 mm. The longest distance was observed in the second molar region, and the shortest in the second premolar region. These findings are also in line with the results of Danesh-Sani et al.[23] and Jung et al.[24] The distance in Danesh-Sani et al.'s study was about 8.17 mm,[23] and in Jung et al.'s study it was 8.8 mm.[24] These values are a little higher than those obtained in the present study and the discrepancy may be attributable to racial differences and the number of samples. It indicates that the distance of PSAA from the second molar region to the first molar and second premolar regions decreases, but it increases in the first premolar region due to the more cranial position of the sinus floor and a higher artery position relative to the infraorbital cavity.

In previous studies, the distance from the artery to the floor of the sinus was evaluated based on age and gender. In the present study, it was found that there were no significant differences in the distance from the artery to the floor of the sinus between the age and gender groups.

In this study, the mean diameter of PSAA was 1.37 ±0.61 mm, with the largest diameter observed in the second premolar region, and the smallest in the first molar region. In a study by Danesh-Sani et al., the average diameter was 1.17 mm,[23] in Chitsazi et al.'s study it was 1.37 mm,[15] and in Güncü et al.'s study it was 1.3 mm,[18] all of which are in agreement with the present results. All of these previous studies did their evaluations using CBCT images. Studies using CT reported larger diameters, indicating differences in the measurement instruments. Researchers that evaluated the diameter of PSAA in cadaver, such as Ella et al.[25] and Hur et al.,[26] reported diameters of 1.2 mm and 0.8 mm, respectively, which are smaller than the diameters reported in CBCT studies. There is a direct relationship between the artery diameter and the likelihood of bleeding during sinus lift surgery. Consequently, with diameters greater than 2 mm, the probability of bleeding increases.[27] According to the results of the present study, as well as those of previous studies, a diameter greater than 2 mm is not common.

No significant difference was observed between the artery diameter and gender, which agrees with the results obtained by Mardinger et al.[19] and Chitsazi et al.,[15] but is in contrast to Khojastehpour et al.[16]

In this study, no significant difference was found between the artery diameter and age, which agrees with Danesh-Sani et al.,[23] but is in contrast to Khojastehpour et al.[16] and Güncü et al.,[18] where the relationship between the diameter and age was significant. In these latter studies, it was found that as age increases, the diameter of the artery increases as well. The reason for these differences across studies may be attributed to the age range in Khojastehpour et al.'s study, which was 25–86 years, with an average of 46 years, which was higher than in this study. We recommend that further studies use a larger sample size, and similar age and gender groups.

Limitations

The limitation of this study was the lack of a uniform distribution for the studied age groups. Thus, differences in the visibility of PSAA within each group were not evaluated separately.

Conclusions

In all age and gender groups, the most common type of PSAA was the intraosseous type. Therefore, due to the high prevalence of the intraosseous type, in most cases of sinus lift surgery there is an increased possibility of PSAA artery damage. The largest artery diameter was observed in the second premolar region. Consequently, the possibility of severe bleeding during sinus lift surgery is the highest in this area. Based on these results, we suggest to provide the lower border of the sinus access window as high as 7 mm to the floor of the sinus.

Ethics approval and consent to participate

The research was approved by the institutional Ethics Committee at Qazvin University of Medical Sciences, Iran. Written informed consent was obtained from all participants.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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