

Anatomic Variation of Posterior Superior Alveolar Artery: Review of Literature and Case Introduction

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The objective of this article is to review topography of posterior superior alveolar artery (PSAA), and to present a case with visualization of a rare anatomic variation of PSAA. An electronic search was undertaken to identify articles about topography of PSAA in Medline, Embase, and Google Scholar databases, published between January 1977 and December 2017. Two animal studies, 8 cadaver studies, 18 cone-beam computerized tomography (CBCT) studies, and 2 review articles were found. The animal studies, cadaver studies, and review articles were excluded because they were not about topography of PSAA. Only CBCT studies were included in this review. Accurate knowledge of vital structures in the surgical area is critical during surgical procedures. PSAA should be analyzed during planning sinus lifting with lateral approach. In the present case, a detailed evaluation of patient by CBCT provided the opportunity to find out a rare variation of PSAA with multiple vessels.

Key Words: anatomy, dental implants, imaging, sinus surgery, tomography

INTRODUCTION

Insufficient bone quality and quantity in the maxillary posterior edentulous area is a common limitation of dental implant placement.¹ To overcome this limitation, various techniques are suggested, such as sinus lifting procedures; also, various materials are used as graft in maxillary region.²⁻⁴ Although sinus lifting procedures are predictable and safe, serious complications may arise, such as bleeding.⁵ The clinicians are supposed to have sufficient knowledge about detailed anatomy of posterior superior alveolar artery (PSAA) to avoid bleeding during sinus lifting with lateral approach.⁶

PSAA is the branch of maxillary artery, which supplies lateral sinus wall and overlying membrane with its extraosseous and intraosseous branches. PSAA has a close contact with bone and periosteum and runs on the outside of the maxillary tuberosity.^{7,8} Although the anatomy and location of PSAA are well described in the literature, anomalies and variations are presented.⁹

Cone-beam computerized tomography (CBCT) is a digital imaging modality that provides more accurate information about the anatomical structures.¹⁰ Evaluation of PSAA by using CBCT prior to sinus lifting surgeries enables the clinicians to avoid bleeding easily while preparing bony window and elevating sinus membrane.^{11,12} There are a few studies about

prevalence, localization, length, and diameter of PSAA by using CBCT images.¹³⁻¹⁶ Hence, the aim of this article is to present a case report about multiple intraosseous branching of PSAA and to discuss the review of the literature published between January 1977 and December 2017 in relation to the anatomical and radiographic investigations of PSAA.

MATERIALS AND METHODS

Focused question

Is there a common topography of PSAA for each posterior teeth? Is there any publication about multiple vessels in the lateral sinus wall?

Information sources

An electronic search of literature published in English between January 1977 and December 2017 was carried out by 2 reviewers (E.T.A.D. and O.D.) using PubMed, Embase, and Google Scholar. Reference lists of studies were also hand-searched for relevance. The key terms used for the search included maxillary sinus, cone-beam tomography, and posterior superior alveolar artery.

Selection criteria

Studies were included for the review if the following inclusion criteria were fulfilled: studies specific to PSAA topography, studies with detailed information about PSAA topography, and English-language literature.

Studies that have analysis by using a radiological technique except CBCT, studies without detailed description of PSAA

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TABLE 1
 Extracted data from selected studies*

Study	Number of Patients/Sinuses	Age	Prevalence of PSAA	Diameter of PSAA	Localization of PSAA
Mardinger et al ¹⁵	104/208 (69 F, 35 M)	52.9	114 (55%)	<1 mm: 26% 1–2 mm: 22.1% 2–3 mm: 6.7%	Over 50% type I
Güncü et al ¹⁴	121/242 (72 F, 49 M)	48.73	64.5%	<1 mm: 36.1% 1–2 mm: 51.4% ≥2 mm: 12.3%	68.2% type I 26% type II 5.7% type III
Kim et al ¹⁸	200/400 (100 F, 100 M)	45–65	52%	<1 mm: 13.9% 1–2 mm: 64.9% ≥2 mm: 21.2%	N/A
Rosano et al ¹¹	100/200 (50 F, 50 M)	53.5	94 (47%)	<1 mm: 55.3% 1–2 mm: 40.4% ≥2 mm: 4.3%	N/A
İlgüy et al ¹⁹	135/270 (85 F, 55 M)	43.10	89.3%	<1 mm: 68.9% 0.94 ± 0.26 mm	71.1% type I 13% type II 5.2% type III
Watanabe et al ²⁶	235/280 (140 F, 95 M)	60.2	P1: 28.9% P2: 58.6% M1: 48.2% M2: 41.4%	P1: 1.3 ± 0.6 P2: 1.2 ± 0.7 M1: 1.2 ± 0.6 M2: 1.1 ± 0.5	N/A
Khojastehpour et al ¹²	150/211 (F: 95, M: 116)	46.75	F: 74.7% M: 85.3%	F: 1.04 ± 0.76 M: 1.33 ± 0.69	28.4% (F) 29.3% (M) type I 44.2% (F) 54.3% (M) type II 2.1% (F) (M) 1.7% type III
Lee et al ²²	177/284 (F: 68, M: 109)	55.9	P2: 1.3% M1: 16.7% M2: 34.8%	N/A	P2: 100% type III M1: 77.27% type I, 4.55% type II, 18.18% type III M2: 87.21% type I, 12.79% type II
Shahidi et al ²⁴	198/396 (F: 130, M: 68)	18–45	368 (93%)	N/A	65.7% type I 20.6% type II 13.5% type III
Velasco-Torres et al ¹⁶	394/788 (F: 201, M: 193)	47.2	R: 82.99% L: 86.29%	1.24 ± 0.18	N/A
Pandharpale et al ²¹	50/100 (F: 20, M: 30)	39	F: 12, M: 24 subjects	0.63 ± 0.38	N/A
de Oliveira et al ¹⁷	205/410 (F: 143, M: 62)	35–77	105 (51.2%)	<1 mm: 29% 1–2 mm: 61% ≥2 mm: 10%	N/A
Danesh-Sani et al ²⁸	430/860 (F: 191, M: 239)	53.5	60.6%	<1 mm: 37.8% 1–2 mm: 55.8% ≥2 mm: 6.4%	69.6% type I 24.3% type II 6.1% type III
Chitsazi et al ²⁷	200/400 (F: 68, M: 74)	50.5	142 (71%)	<1 mm: 30.2% 1–2 mm: 59.1% ≥2 mm: 10.5%	73.2% type I 21.7% type II 4.9% type III
Tehranchi et al ²⁰	300/N/A (F: 138, M: 162)	62.4	87%	<1 mm: 20.7% 1–2 mm: 74.8% ≥2 mm: 4.5%	47% type I 47% type II 6% type III
Lozano-Carrascal et al ²⁹	284/284 (F: 54% , M: 46%)	59.5	48.6%	<1 mm: 36.5% 1–2 mm: 28.9% ≥2 mm: 34.6%	38.46% type I 53.85% type II 7.69% type III
Keceli et al ¹³	597/1194 (F: 285, M: 312)	50.5	49.8%	<1 mm: 29% 1–2 mm: 25.2% ≥2 mm: 0.7%	30.2% type I 18.2% type II 1.4% type III

*PSAA indicates posterior superior alveolar artery; M, male; F, female; R, right; L, left; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; N/A, not available.

TABLE 1
Extended

Distance Between Lower Border of PSAA and Crest	Distance Between Lower Border of PSAA and Sinus Floor	Distance Between PSAA and Medial Wall	Dentate/Edentulous	Ridge Height
P1: 22.548 P2: 19.0541 M1: 16.9221 M2: 18.8802 18 ± 4.9	N/A	N/A	Totally edentulous: 66% Partially edentulous: 33%	A + B type: 12.56 C type: 8.00 D type: 4.80 E type: 2.10 N/A
P: 18.9 ± 4.21 M: 15.45 ± 4.04	N/A	N/A	N/A	N/A
11.25 ± 2.99	N/A	N/A	N/A	3.60 ± 1.28 mm
F: 16.79 ± 3.79 M: 17 ± 2.94	N/A	F: 13.27 ± 2.82 M: 14.03 ± 2.44	Edentulous: 116, Dentate: 154	F: 7.50 ± 3.03 M: 8.34 ± 3.43
P1: 24.1 ± 4.7 P2: 21.3 ± 5.4 M1: 15.4 ± 5.4 M2: 15.3 ± 5.3 F: 14.91 ± 9.64 M: 17.53 ± 9.17	P1: 10.4 ± 6.0 P2: 10.4 ± 6.2 M1: 9.0 ± 5.1 M2: 8.5 ± 4.3 N/A	N/A	N/A	N/A
P2: 23.45 ± 2.81 M1: 15.92 ± 2.65 M2: 16.61 ± 2.92	P2: 5.89 ± 6.11 M1: 11.83 ± 3.16 M2: 12.21 ± 2.87	N/A	Totally edentulous: 21% Partially edentulous: 79%	P2: 17.56 ± 3.30 M1: 4.19 ± 2.15 M2: 4.21 ± 1.86
N/A	N/A	R: 24.8657 ± 4.94112 L: 24.8214 ± 4.71998	N/A	N/A
13.40 ± 3.72	6.86 ± 3.47	N/A	R-totally edentulous: 31.47% R-partially edentulous: 31.75% R-dentate: 36.80% L-totally edentulous: 29.70% L-partially edentulous: 28.95% L-dentate: 40.36%	N/A
R-M1: 17.19 ± 4.6 R-M2: 17.17 ± 3.68 L-M1: 17.75 ± 3.81 L-M2: 17.00 ± 3.28 15.05 ± 4.47	R-M1: 9.95 ± 3.79 R-M2: 9.96 ± 3.25 L-M1: 10.48 ± 3.21 L-M2: 9.49 ± 3.12 9.62 ± 4.59	R-M1: 14.64 ± 4.06 R-M2: 14.28 ± 2.80 L-M1: 15.50 ± 3.35 L-M2: 15.04 ± 2.76 N/A	N/A	R-M1: 9.97 ± 3.89 R-M2: 9.54 ± 3.06 L-M1: 9.84 ± 3.53 L-M2: 9.79 ± 3.56 N/A
N/A	P1: 8.57 P2: 8.45 M1: 8.09 M2: 9.27	N/A	N/A	N/A
16.17 ± 1.63	N/A	11.65 ± 1.21	Edentulous: 79 Dentate: 63	N/A
16.7 ± 3.96	N/A	N/A	N/A	A type: 22.2 B type: 19.81 C type: 17.3 D type: 14.5 E type: 9.6
13.15 ± 3.71	N/A	N/A	N/A	P2: 8.66 ± 3.95 M1: 4.90 ± 2.28 M2: 5.26 ± 2.13
14.15 ± 5.91	N/A	N/A	N/A	7.58 ± 4.58

TABLE 1
Extended

Prevalence of Sinus Septa	Prevalence of Pathology	Sinus Membrane Thickness
N/A	N/A	N/A
16.1%	24.8%	N/A
N/A	N/A	N/A
N/A	N/A	N/A
55.2%	F: 48.8% M: 68.2%	57.4%
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
45.4%	Hypoplasia: 6.5% Exostosis: 3.28%	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
26%	45.7%	N/A
N/A	N/A	N/A
Bucco-palatal: 20.56% Sagittal: 3.74% Horizontal: 0% 30.82%	N/A	1.82 ± 1.59
	N/A	Dentate: 3.73 ± 4.60 Edentulous: 4.06 ± 5.65

topography, and non-English-language literature were excluded from this study.

Data extraction

The following data were extracted from selected studies: authors and year of publication, number of patients and sinuses, age, prevalence of PSAA, diameter of PSAA, localization of PSAA, distance between lower border of PSAA and crest, distance between lower border of PSAA and sinus floor, distance between PSAA and medial wall, number/percentage of dentate/edentulous patients, ridge height, prevalence of sinus septa, prevalence of pathology, and sinus membrane thickness.

RESULTS

After removing duplicated studies, the literature search resulted with total of 2 animal studies, 8 cadaver studies, 18 CBCT studies, and 2 review articles. The animal studies, cadaver studies, and review articles were excluded because they were not about topography of PSAA. Only 18 CBCT studies were included in this systematic review according to inclusion and exclusion criteria and all extracted data shown in Table 1.

Various results of PSAA analysis were found like according to gender, right/left side, tooth areas, etc. To classify of PSAA diameter, Mardinger et al¹⁵ used the subgroups as equal and less than 1 mm, between 1 and 2 mm, and between 2 and 3 mm. Others made a classification with subgroups named: equal and less than 1 mm, between 1 and 2 mm, and equal and higher than 2 mm.^{13,14,17,18} Besides, a few authors gave information about mean value of PSAA diameter.^{16,19}

While Khojastehpour et al¹² classified residual height as: more than 10 mm, and equal and less than 10 mm, some authors classified ridge height according to Lekholm and Zarb.^{15,20} However, some authors informed mean value of ridge height without any classification.^{11,21,22} In this review, localization of PSAA classification was presented as: type I (intraosseous), type II (below the membrane), and type III (outer cortex, extraosseous).

CASE REPORT

A 65-year-old male patient was referred to the Department of Periodontics, College of Dentistry, University of Illinois at Chicago for a routine dental examination. The patient did not have any medical systemic diseases and conditions. Intraoral examination revealed periodontal disease. The patient, presenting edentulous area in the upper left first molar, has demanded a treatment with dental endosseous implant. CBCT (iCAT, Model 17-19, Imaging Sciences International, Hatfield, Pa; voxel size 0.3 mm, 120 kV, 5mA) was performed for implant planning. While evaluation of CBCT scans, 3 vessels in the lateral sinus wall in the region of maxillary right second premolar and maxillary left first molar were detected. Besides, 2 vessels in the lateral sinus wall were also inspected in right first molar area by using CBCT.

Description of the topography of right PSAA (Figure 1): No PSAA was detected and no relation with sinus was found in first

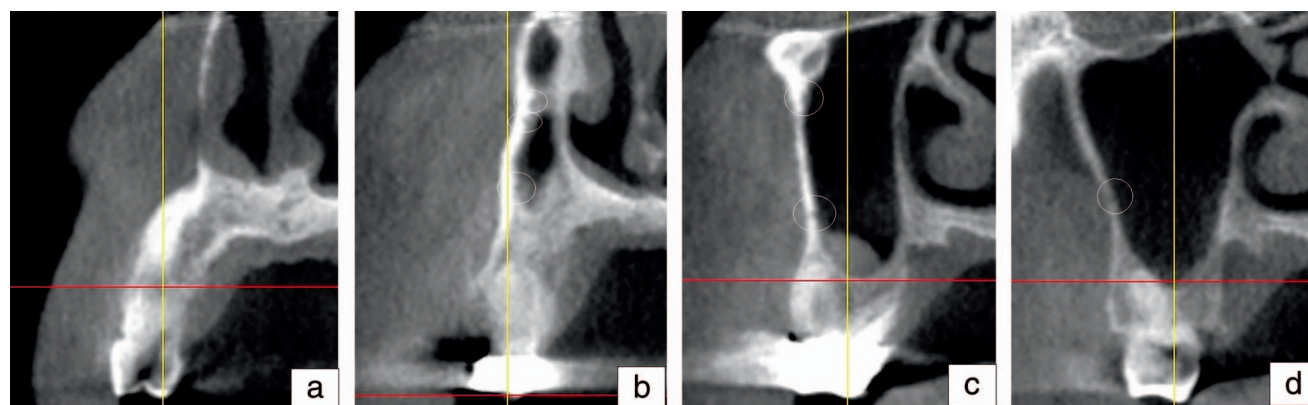


FIGURE 1. Right posterior superior alveolar artery for each teeth region (vessels are showed by using white circle). (a) First premolar region. (b) Second premolar region. (c) First molar region. (d) Second molar region.

premolar area. In second premolar region, 3 vessels were localized below the Schneiderian membrane. The widest vessel was medial vessel (0.86 mm) and the narrowest one was measured as coronal vessel (0.69 mm). The distances between PSAA and crest were measured 16.26 mm, 26.89 mm, and 29.64 mm. Two vessels were observed at the area of the first molar. The vessels were both localized below the Schneiderian membrane. The diameter of coronal vessel (0.73 mm) was wider than apical vessel (0.55 mm). The distances between PSAA and crest were noted 18.28 mm and 35.09 mm. In the second molar area, a single vessel was detected below the Schneiderian membrane with the diameter of 0.82 mm. The distance between PSAA and crest in second molar region was 20.38 mm.

On the left side, no PSAA was detected and no relation with sinus was found in the first and second premolar regions. Three vessels were noted at the area of first molar. While diameter of the medial vessel was measured widest, the narrowest vessel was apical vessel for the first molar region. In the first molar region, the distances between PSAA and crest were noted 17.81 mm, 31.45 mm, and 33.52 mm. At the area of second molar, a single vessel was reported below the Schneiderian membrane and its diameter was 0.52 mm. The distance between PSAA and crest in second molar region was 20.74 mm (Figure 2).

Single edentulous area was noted in the left first molar region. Although no major sinus pathology and no sinus septa was observed, hemispherical membrane thickening was noted for right side. All PSAAs were examined in details on CBCT images and demonstrated in Table 2.

DISCUSSION

Placement of dental implants with sinus lifting surgeries in the atrophic posterior maxilla have become a common procedure in recent years.⁵ During this procedure, the practitioners should take care with anatomic structures, especially on PSAA to avoid bleeding.⁸ A few surgical techniques have been presented like double window technique to avoid bleeding while sinus lifting procedures.²³ In this review article, we found a difference about the prevalence of PSAA 47% and 93%.^{11,17,19,24} Varela-Centelles et al²⁵ presented a pooled prevalence of PSAA as 62.02% in their systematic review and meta-analysis. Watanabe et al²⁶ and Lee et al²² calculated prevalence of PSAA for each tooth. Watanabe et al also presented prevalence of PSAA at the regions of first premolar, second premolar, first molar, and second molar 28.9%, 58.6%, 48.2%, and 41.4%, respectively.²⁶ Lee et al²² noted 1.3% for second premolar area, 16.7% for first molar area, and 34.8% for second molar area. The mean

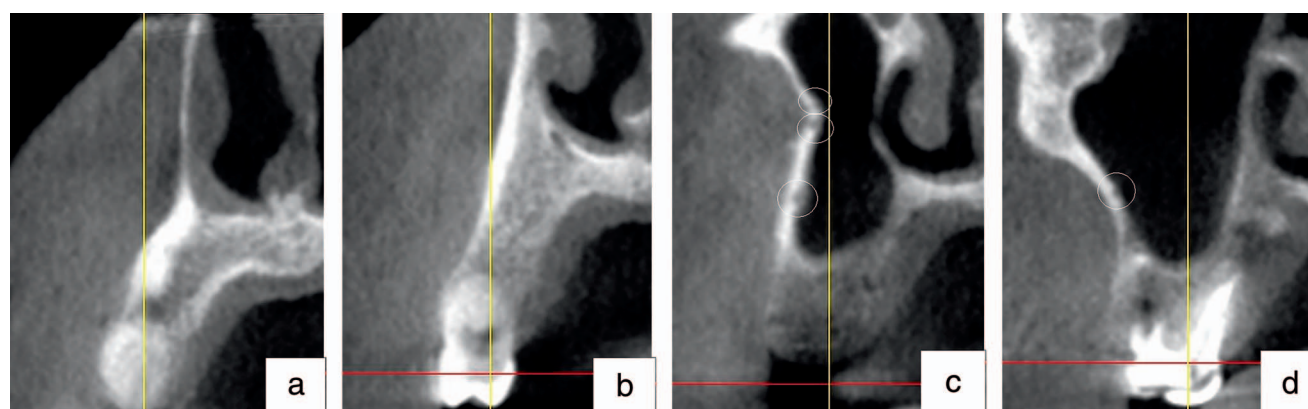


FIGURE 2. Left posterior superior alveolar artery for each teeth region (vessels are showed by using white circle). (a) First premolar region. (b) Second premolar region. (c) First molar region. (d) Second molar region.

TABLE 2
Descriptive topography of posterior superior alveolar artery (PSAA) for right and left side*

Area	Number of Vessels	Localization of PSAA	Diameter of PSAA	Distance between Lower Border of PSAA and Crest	Buccal Bone Thickness	Palatal Bone Thickness
#2	No PSAA	No PSAA	No PSAA	No PSAA	No relation with sinus	No relation with sinus
#3	3	Below the membrane (all)	0.71 mm (apical) 0.86 mm (medial) 0.69 mm (coronal)	16.26 mm (apical) 26.89 mm (medial) 29.64 mm (coronal)	1.79 mm (apical) 1.53 mm (medial) 2.04 mm (coronal)	8.31 mm
#4	2	Below the membrane (both)	0.55 mm (apical) 0.73 mm (coronal)	18.28 mm (apical) 35.09 mm (coronal)	1.39 mm (apical) 2.08 mm (coronal)	3.17 mm
#5	1	Below the membrane	0.82 mm	20.38 mm	1.55 mm	2.78 mm
#12	No PSAA	No PSAA	No PSAA	No PSAA	No relation with sinus	No relation with sinus
#13	No PSAA	No PSAA	No PSAA	No PSAA	No relation with sinus	No relation with sinus
#14	3	Below the membrane (all)	0.52 mm (apical) 0.69 mm (medial) 0.62 mm (coronal)	17.81 mm (apical) 31.45 mm (medial) 33.52 mm (coronal)	1.70 mm (apical) 7.81 mm (medial) 8.73 mm (coronal)	3.35 mm
#15	1	Below the membrane	0.52 mm	20.74 mm	1.38 mm	1.70 mm

*Teeth were numbered by American Dental Association (ADA) tooth numbering system.

diameter of PSAA was reported between 0.63 ± 0.38 mm and 1.24 ± 0.18 mm.²¹ In almost all studies the most frequent localization of PSAA was denoted as intraosseous.^{13,27,28} However, Lozano-Carrascal et al²⁹ and Khojastehpour et al¹² informed that it was below the membrane.

In the present study, the distance between lower border of PSAA and crest was ranged from 11.25 ± 2.99 mm to 18.00 ± 4.90 mm. It also had lower values in posterior region than anterior.^{11,14,20,26} Contradictories were found for the distance between lower border of PSAA and sinus floor. Although Watanabe et al²⁶ reported that the distance between lower border of PSAA and sinus floor was higher in anterior areas, Lee et al²² noted that it was higher in posterior areas. In another study, the distance between sinus floor and crest was lower in the second molar region than the first molar region.²¹ The average distance between PSAA and the medial wall was noted as 8.35 ± 6.40 mm and 24.86 ± 4.94 mm in some studies.^{12,14,24} Tehranchi et al²⁰ presented the distance between PSAA and nasal septum, and the distance between PSAA and zygomatic arch, 26.51 ± 3.52 mm and 25.59 ± 4.89 mm, respectively.

In this review, prevalence of sinus septa was found between 16.1% and 55.2%.^{14,19,30} The frequent localization of sinus septa was noted as anterior,^{13,24} and it was longer in the anterior region (6.46 ± 3.75 mm) than the posterior (5.12 ± 2.88 mm).¹³ The prevalence of pathology was calculated between 24.8% and 68.2% in some studies.^{14,19,27} Sinus membrane thickening was presented 57.2% by Ilguy et al.¹⁹ The most common sinus membrane thickening type was noted as flat (19.9%) and the second was hemispherical (12.6%).¹³ Although various values were reported as lateral wall thickness,^{13,29} Danesh-Sani et al²⁸ presented that it was decreasing posteriorly.

The mean ridge height was found between 3.6 mm and 17.56 ± 3.30 mm.^{11,22} The average ridge height was noted lower in molar regions than premolars.^{22,29} Some authors classified ridge height according to Lekholm and Zarb.^{15,20} The width of residual ridge was both wider apically¹³ and posteriorly.²⁹ Besides residual ridge bone density was calculated

330.93 ± 211.02 mm in first molar region by Lozano-Carrascal et al.²⁹

To the best of our knowledge, only 1 case report and review of literature, written by Wolf et al,⁹ was found while searching databases. They reported 3 vessels in the lateral sinus wall with limited information. They presented the distance between vessels and crest apical to coronal 24.6 mm, 19.5 mm, and 13.5 mm, respectively.⁹

When topography of PSAA for each individual site was considered, to best our knowledge, very limited research was published in the English language.^{15,21,26} As a result of the present study, taking care of branching and topography of PSAA is essential to overcome intraoperative complications like bleeding. In addition to the literature, data collection type about PSAA topography of included articles were also presented in this present study. When interpreting the results of this study, the following limitations should be considered. No anatomical evaluation was included in this study. Besides, any statistical test could not be performed for analyzing review.

CONCLUSIONS

Accurate knowledge of vital structures in the surgical area is critical during surgical procedures. PSAA should be analyzed while planning sinus lifting with lateral approach to avoid bleeding during surgery. In the present case, a detailed evaluation of patient by CBCT provided us the opportunity to find out PSAA with multiple vessels. We suggest that CBCT imaging may be an effective tool to diagnose these variations. Future studies with more subjects, including radiological and anatomical evaluations, should be planned to detect topography and variations of PSAA.

ABBREVIATIONS

ADA: American Dental Association
CBCT: cone-beam computerized tomography

F: female
 L: left
 M: male
 M: molar
 M1: first molar
 M2: second molar
 N/A: not available
 P: premolar
 P1: first premolar
 P2: second premolar
 PSAA: posterior superior alveolar artery
 R: right
 RH: residual height

NOTE

The authors have no acknowledgments nor conflicts of interest to declare.

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