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Evaluation of anatomic variations in the posterior superior alveolar artery – A Cone-beam Computed Tomography (CBCT) study

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Abstract

Anatomical variation of the course of posterior superior alveolar artery (PSAA) within maxillary bone are vital information for surgeons before any maxillary surgery. This study was designed to evaluate the variations of PSAA by determining the prevalence of intraosseous PSAA and assessing the anatomical reference points and diameter of the PSAA. Comparison between dentate and edentulous alveolus was also done. One hundred CBCT images were included in this study to enumerate the prevalence of intraosseous PSAA in maxilla. Anatomical reference points which include the horizontal position of the PSAA and the vertical distance from the PSAA to the maxillary sinus floor and alveolar crest were identified. The diameter and horizontal position of PSAA were also analysed. The results were tested using independent t-test and chi square test. The PSAA was seen in 73.5% of the cases and 70.1% were located intraosseously. There was no significant difference in the vertical distance between PSAA and alveolar crest, as well as between maxillary sinus floor and alveolar crest for dentate and edentulous patients. Meanwhile, there was a significantly greater vertical distance between the PSAA and the maxillary sinus floor in edentulous (9.24 ± 4.75 mm) than in dentate patients (6.78 ± 3.43 mm) with p-value of 0.002. Mean diameter of the canal was 1.09 ± 0.43 mm. In conclusion, this study provides useful information regarding the most prevalent location and diameter of the PSAA which indicates the importance of preoperative evaluation through CBCT to reduce the risk of intraoperative bleeding that may complicate the treatment.

Keywords: *cone beam computed tomography, maxillary sinus, maxillary artery, posterior superior alveolar artery*

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Introduction

Posterior superior alveolar artery (PSAA) is one of the fifteen branches of the maxillary artery, which is the terminal division of the external carotid artery. Maxillary artery can pass superficially or deeply to the lateral pterygoid muscle and enters the pterygopalatine fossa where it divides into its terminal branches, one of them being the posterior superior alveolar artery (Gofur and Khalili, 2023). The PSAA is one of the main contributors to the maxillary structures whereby it divides into several branches in which some of them enter the alveolar canals to supply the molar and premolar teeth as well as the maxillary sinus lining. This is called the dental branch of the PSAA. This artery travels intraosseously and will create a horizontal anastomosis with the infraorbital artery (Yusof *et al.*, 2020). The other branches would travel towards the alveolar process to supply the posterior

buccal gingiva. The PSAA shares the same route as the posterior superior alveolar nerve as they innervate the same structure (Cheng and Hacking, 2023).

The course of the PSAA and their location within the maxillary structures can vary distinctly and can exist extraosseous or intraosseously (Pandharbale *et al.*, 2016). Therefore, it is vital to have the knowledge of the anatomical variations and landmarks of the PSAA especially when performing surgeries that involve the posterior maxilla area such as the Le Fort 1 osteotomy, the maxillary sinus augmentation and subsequent insertion of dental implants (Padovani *et al.*, 2020). The assessment of the anatomy of the maxillary sinus and surrounding vital structures including the PSAA can avoid any unnecessary surgical complications such as intraoperative haemorrhage due to the close proximity between the artery and the maxillary sinus. It was also reported that when a haemorrhage occurs during a sinus lifting procedure, the surgeon's access to the surgical field will be diminished and can potentially cause perforation to the sinus membrane (Panjnoush *et al.*, 2017)

Review of the current literature on the detection rate of the PSAA found that the artery is present in CBCT in more than half of the cases (Güncü *et al*., 2011; Jung *et al*., 2011; Panjnoush *et al.*, 2017). This shows that the prevalence of the artery is relatively high in CBCT images. However, the undetected canal of the artery in a CT scan does not neglect its existence as it may not be visible due to the small diameter and the lesser definition of images in CT scans compared to CBCT scans. Another study suggested that the diameter would decrease with age (Yusof *et al.*, 2020). Hence, the type of device used for the imaging also plays an important role for preoperative assessment in pre-prosthetic surgery of edentulous elder patients.

There was also a huge variability in the horizontal and vertical position of the artery reported in the literature (Güncü *et al.*, 2011; Jung et al., 2011; Panjnoush et al., 2017). The location of the artery is also influenced by the status of the dentition in the posterior maxilla where it reported a greater distance between the artery and sinus floor in edentulous ridges, but shortest at the first molar region and longest at the first premolar region (Panjnoush *et al.*, 2017; Yusof *et al.*, 2020). The importance of identifying the location of this artery is particularly significant in the lateral wall approach of the sinus lift procedure where the flap and the bony window created may be within the surgical field. This may limit the surgical access to avoid iatrogenic damage to the artery whereby it may lead to intraoperative haemorrhage and poor vascular supply which will hinder the healing of the bone graft in sinus lift (Ella *et al.,* 2008; Rysz *et al.*, 2014).

Therefore, the aim of this study was to determine the presence of the PSAA detectable in CBCT of posterior maxilla in dentate and edentulous patients, as well as to determine the horizontal and vertical locations of the PSAA and to calculate the mean diameter of the PSAA in dentate and edentulous patients.

Materials and Methods

A cross-sectional study performed on CBCT images of the posterior maxilla of patients presented to the Oral Radiology Unit in a dental institute from 2011 until 2016 was conducted upon ethical approval by the IIUM Research Ethical Committee (IREC 2021-159). The CBCT images were identified through assessment of the radiographic database available in the institute. The CBCT scans of adult patients aged above 18-years which had the posterior maxilla and maxillary sinus within the field of view regardless of the imaging indication were collected. Patients with a history of maxillary fracture, surgery or bony pathology were excluded from the study. Low quality CBCT images hindering the investigation of the posterior maxilla were also excluded from this study. In order to identify the prevalence of the posterior superior alveolar artery in dentate and edentulous patients, assuming a two-sided significance level of 95%, a power of 80% while expecting a 30% to 70% ratio

of prevalence, using the Fleiss formula, a total sample size of 58 CBCT images is required.

The CBCT images collected were obtained using Planmeca Promax 3D imaging device (Planmeca, Helsinki, Finland) at 90kV, with a voxel size of 0.2 mm and a field of view of 18 - 20 cm, being the scan time of 18 seconds. The CBCT 3D images were then analysed and measured using Planmeca Romexis version 2.2 software program (Planmeca, Helsinki, Finland). Two researchers underwent training for the Planmeca Romexis software and a pilot assessment in observing 10 CBCT images for the intra-observer reliability testing was done to ensure reproducibility of the identification of landmarks prior to data collection. The inter-rater reliability showed a strong agreement between two researchers with Intraclass Correlation Coefficient (ICC) ranging from 0.89 to 0.91 for all the variables.

The assessment of the vertical position of the posterior superior alveolar artery (PSAA) in relation to other anatomical landmarks include the vertical distance between the lower border of the PSAA canal to the alveolar crest (A), vertical distance between the lower border of the PSAA canal to the maxillary sinus floor (B), and vertical distance between the maxillary sinus floor to the alveolar crest (C) (Figure 1). The horizontal position of the PSAA in relation to the sinus wall was also evaluated and categorised into intrasinus, intraosseous and superficial following Danesh-Sani definition of horizontal position of PSAA (Danesh-Sani *et al*. 2017). (Figure 2). Table 1 summarised the definition of the horizontal positions of the PSAA within the lateral wall of the maxillary sinus. The diameter of the PSAA canal was also measured (Figure 3).

The data obtained were collected and analysed using IBM® SPSS® Statistics Version 23 (IBM Corporation, Armonk, USA). Demographic data of the posterior maxilla images such as the age, gender, side, dental status and the presence of intraosseous PSAA were recorded and analysed. The inter-observer reliability was done using a two-way mixed, absolute agreement, 95% confidence interval ICC for every variable.

The prevalence of the intraosseous PSAA in the CBCT of the dentate and edentulous posterior maxilla was compared and tested using Chi-square test. The horizontal position of the intraosseous PSAA in the lateral wall of the maxillary sinus of the dentate and edentulous posterior maxilla was also compared and tested using Chi square test. Meanwhile, the vertical distances of the PSAA to the alveolar ridge and maxillary sinus floor, as well as the vertical distance of alveolar crest to the sinus floor were obtained and compared between dentate and edentulous patients using independent t-test. The diameter of the PSAA was also recorded and compared using independent t-test.

Table 1. Different horizontal position of PSAA and their definition.

Horizontal position of PSAA	Definition
Intrasinus	Below sinus wall towards the maxillary sinus
Intraosseous	Within the maxillary sinus wall
Superficial	Outside and away from maxillary sinus wall

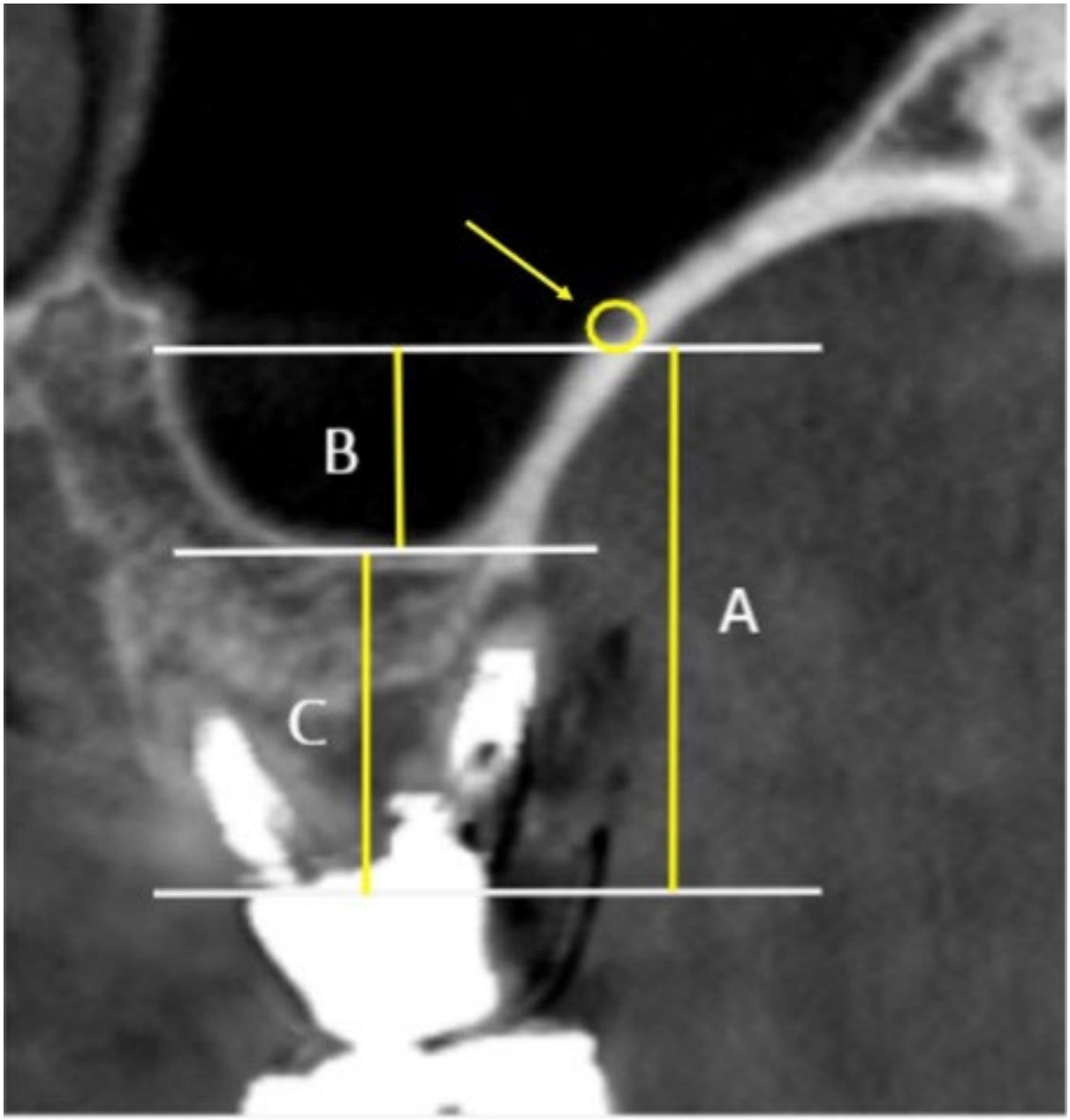

Figure 1. A magnified coronal plane from multiplanar reconstruction (MPR) view was used to detect the PSAA on the lateral wall of the posterior maxilla. The arrow is pointing towards PSAA canal that is also encircled. After identifying the PSAA canal, digital measurements for the vertical position were made on the coronal view. Horizontal lines were drawn at the lower border of the canal, maxillary sinus floor and alveolar crest. Those lines were then used to measure the vertical distance between the lower border of the canal to the alveolar crest (A), vertical distance between the lower border of the canal to the maxillary sinus floor (B), and vertical distance between the maxillary sinus floor to the alveolar crest (C).

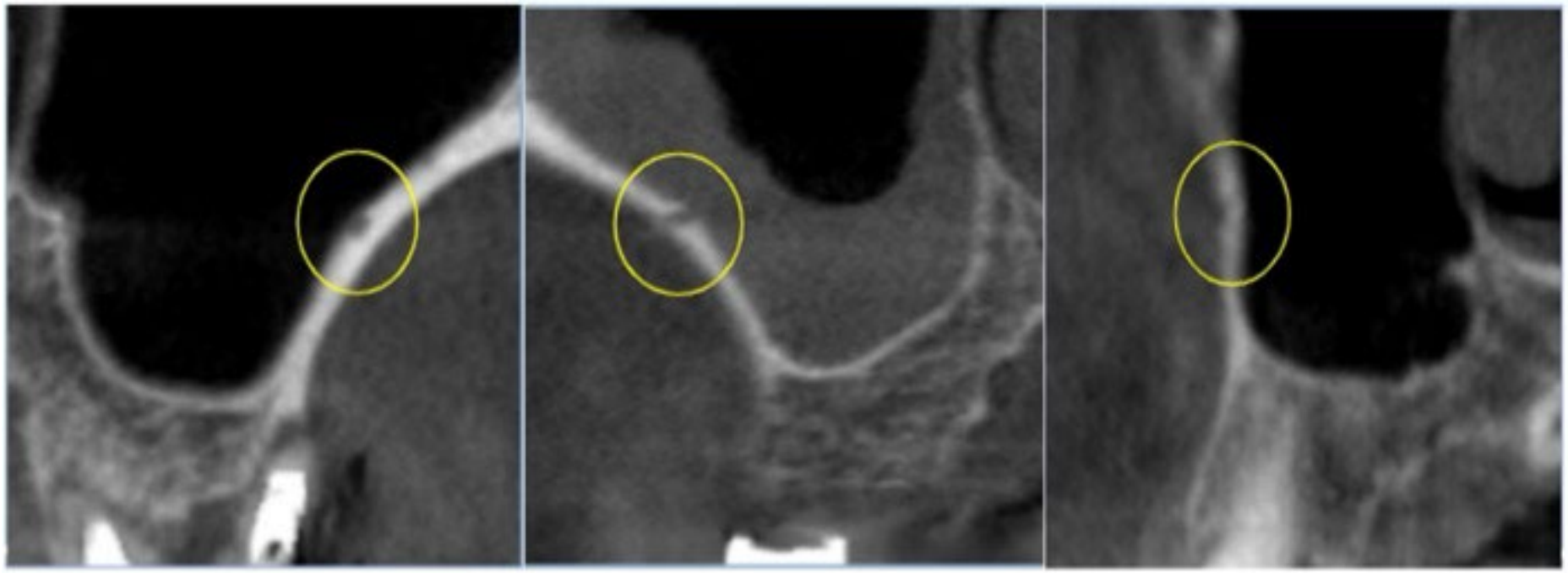

Figure 2. A magnified coronal slice of the MPR view was also used to detect the different horizontal positions of the PSAA in the CBCT images: (from left to right: intrasinus, intraosseous, superficial).

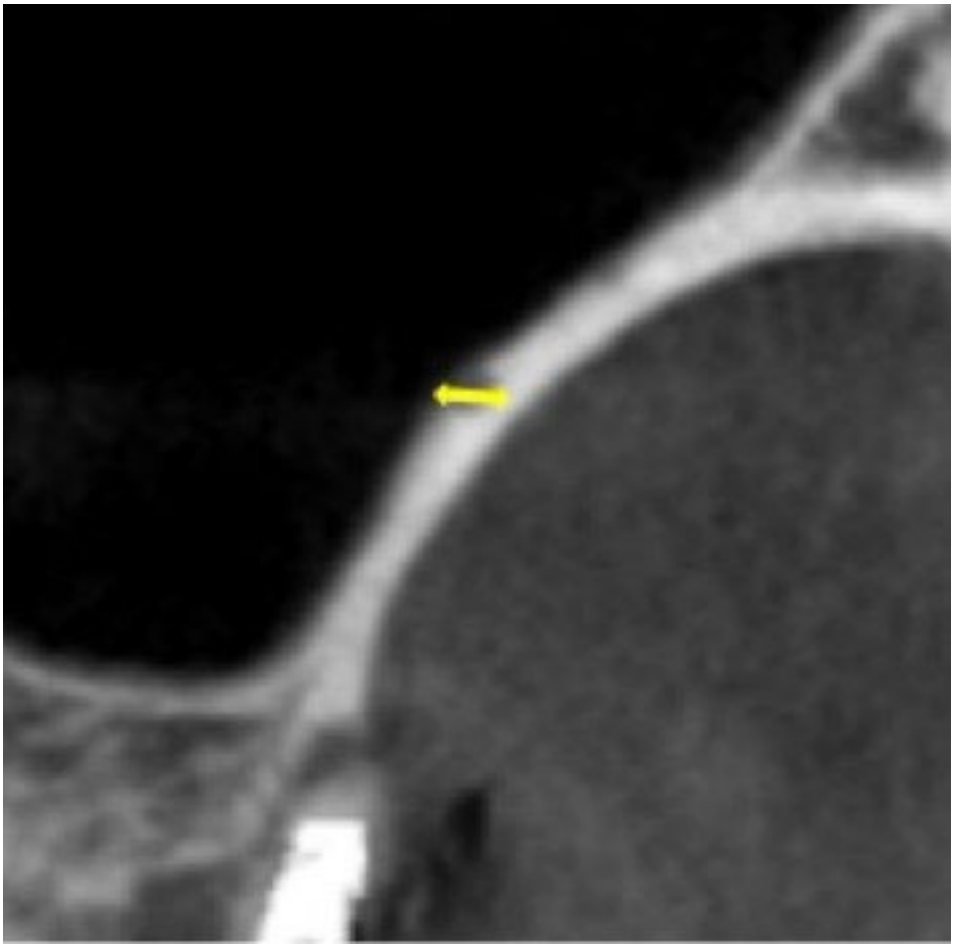

Figure 3. A magnified view of the coronal slice of the CBCT image showing the distance from a point on one side of the canal to a point on the other side going through the center in a horizontal plane was used to measure the diameter of the canal.

Results

A total of 100 CBCT scans (49 males; 51 females) were selected for observation and investigation. Eighty-six of the CBCT scans of the posterior maxilla were dentate and 14 are edentulous. The total mean age of the patients was 34 years old, ranging between 16 to 74 with median age of 24 years old. For dentate patients, the mean age was 28.56 while for edentulous patients, the mean age was 62.29 with a significantly higher age in the edentulous group ($p = 0.000$). Assessment of the gender revealed 47.7% ($n = 41$) males and 52.3% (45) females were dentate, while 57.1% (8) males and 42.9% (6) females were edentulous ($p = 0.806$) (Table 2). There were no significant differences of the gender distribution when compared between the dentate and edentulous.

Of all the posterior maxilla examined, 73.5% (147) showed the presence of the PSAA with 69.2% ($n = 119$) out of the dentate group having the PSAA present and a total of 100% (28) in the edentulous group having the PSAA present. There was a statistically significant difference for the prevalence of PSAA between dentate and edentulous posterior maxilla ($p = 0.001$, Table 3).

Table 2. Demographic data and descriptive statistics of the CBCT images of the posterior maxilla.

	Dentate			Edentulous			
	Mean	SD	Range	Mean	SD	Range	*p*-value
Age	28.56	14.28	16-71	62.29	8.37	42-74	*0.000
	n	**%**		**n**	**%**		***p*-value**
Gender							0.806
Male	41	47.7		8	57.1		
Female	45	52.3		6	42.9		

*Independent *t*-test with *p*-value <0.05
†Chi square test with *p*-value <0.05

Table 3. Prevalence of the PSAA present in the posterior maxilla.

	% of PSAA present in posterior maxilla (no. of PSAA present / total posterior maxilla)			
Presence of PSAA	**Dentate**	**Edentulous**	**Total**	***p*-value**
Present	69.2% (119/172)	100% (28/28)	73.5% (147/200)	†0.001
Absent	30.8% (53/172)	0 (0/28)	26.5% (53/200)	

†Chi square test with *p* value < 0.05

Table 4 demonstrated the horizontal position of the PSAA in the maxillary sinus between dentate and edentulous posterior maxilla. Among the 147 arteries present in the CBCT, 103 of the PSAA (70.1%) were located intraosseously. Meanwhile, 42 (28.6%) and 2 (1.4%) of the PSAA were located intrasinus and superficially, respectively. There was no statistical significant difference among the dentate and edentulous posterior maxilla when comparing their horizontal positions (p = 0.652).

The vertical distances from the lower border of the canal to the alveolar crest and sinus floor were shown in Table 5. The total mean vertical distance between the lower border of the PSAA canal and the alveolar crest is 17.62 ± 4.72 mm, with those in edentulous posterior maxilla having greater mean of 19.07 ± 5.41 mm, as compared to those in dentate posterior maxilla (17.28 ± 4.50 mm). This difference was not statistically significant with p = 0.071.

Table 4. Horizontal position of PSAA.

Horizontal position of PSAA	% of PSAA horizontal position (n / total no of PSAA)			*p*-value
	Dentate	Edentulous	Total	
Intrasinus (%)	28.6 (34/119)	28.6 (8/28)	28.6 (42/147)	0.652
Intraosseous (%)	69.7 (83/119)	71.4 (20/28)	70.1 (103/147)	
Superficial (%)	1.7 (2/119)	0 (0/28)	1.4 (2/147)	

†Chi square test with *p* value < 0.05

Table 5. Vertical distances related to the PSAA between dentate and edentulous posterior maxilla.

Vertical distance (mm)	Dentate (n=119)		Edentulous (n=28)		*p*-value
	Mean (SD)	Min Max	Mean (SD)	Min-Max	
Between lower border of canal and alveolar crest, A	17.28 (4.5)	8.04 - 29.80	19.07 (5.41)	9.20 - 30.00	0.071
Between lower border of canal and maxillary sinus, B	6.78 (3.43)	0.40 - 17.00	9.24 (4.75)	0.60 - 23.00	*0.002
Between maxillary sinus and alveolar crest, C	10.52 (0.38)	1.02 - 26.00	9.83 (0.88)	2.60 - 20.80	0.439

*Independent t-test with p-value <0.05

On the other hand, the total mean vertical distance between the lower border of the PSAA canal to the maxillary sinus floor was 7.24 ± 3.84 mm. It showed a statistically significant difference between the dentate and edentulous posterior maxilla where the distance was greater in edentulous posterior maxilla when compared to the dentate posterior maxilla, with a mean vertical distance of 9.24 ± 4.75 mm for the edentulous posterior maxilla and a mean vertical distance of 6.78 ± 3.43 mm in the dentate posterior maxilla (p = 0.002).

The assessment of the vertical distance between the maxillary sinus floor and the alveolar crest showed a total mean distance of 10.39 ± 4.23 mm, in which it demonstrated a slightly higher vertical distance in the dentate posterior maxilla (10.52 ± 0.38 mm) when compared to edentulous posterior maxilla (9.83 ± 0.88 mm). Despite the difference in the vertical height for the dentate and edentulous posterior maxilla, it was not statistically significant (p = 0.439).

As shown in Table 6, the mean diameter of the PSAA canal was 1.09 ± 0.43 mm regardless of the dental status. In the dentate and edentulous posterior maxilla, the mean diameters of the canals were measured 1.10 ± 0.44 mm and 1.02 ± 0.38 mm respectively. There was no statistical significance between dentate and edentulous posterior maxilla (p = 0.383).

Table 6. Diameter of PSAA.

	Dentate (n=119)		Edentulous (n=28)		*p*-value
	Mean (SD)	Min Max	Mean (SD)	Min Max	
Diameter of PSAA (mm)	1.10 (0.44)	0.30 - 2.04	1.02 (0.38)	0.30 - 1.80	0.383

*Independent *t*-test with *p*-value <0.05

Discussion

The importance of taking a CBCT prior to any posterior maxillary surgery to locate the PSAA has been advocated by many surgeons to ensure intraoperative haemorrhage due to the damage to the PSAA can be prevented. This current study found that the PSAA could be detected in the majority of the posterior maxillary CBCT scans (73.5%) with 69% of them being detected in dentate patients and 100% in edentulous patients. Although there is a huge variability in the detection of PSAA in the lateral wall of the maxillary sinus, the prevalence of PSAA present in our study sample were within the reported range of 64% to 92% (Anamali *et al.*, 2015; Güncü *et al.,* 2011). Our study found that the PSAA is significantly more prevalent in edentulous patients (p = 0.001) as 100% of the edentulous posterior maxilla showed the presence of intraosseous PSAA. This finding is supported by a clinical tomographic study of the intraosseous PSAA done by Dias *et al.* where there was also a significantly higher prevalence of PSAA in edentulous compared to the dentate patients (Dias *et al.*, 2019). This finding serves as an important clinical implication as these edentulous patients are the major candidates for the pre-implant sinus lifting procedure. Several studies supported the importance of detecting the PSAA using CBCT prior to any surgical procedure involving the posterior maxilla to reduce the inadvertent injury to the PSAA (Chitsazi *et al.*, 2017; Dias *et al.*, 2019; Shahidi *et al*., 2016).

When the PSAA is not detected in the maxillary sinus walls, the PSAA is possibly having an extra-osseous course where the artery may be travelling within the buccal mucosa, underneath the periosteum or inside the sinus wall. When this study assessed the horizontal position of the artery, the most common position of the artery is in intraosseous with the prevalence of 70% as compared to the other intrasinus and superficial locations. Other studies also found that the most common position of the artery was intraosseous (Chitsazi *et al.*, 2017; Shahidi *et al.*, 2016; Varela-Centelles *et al.*, 2020). There was no statistical significant difference between the dentate and edentulous groups when assessing their horizontal positions. The same result was also reported by Dias *et al*. where the intraosseous PSAA was detected more in edentulous patients as compared to dentate patients (Dias *et al.*, 2019). Other locations of the PSAA were also detected at intrasinusal (28%) and superficial near the periosteum of the buccal cortex (1.4%) in tandem with other CBCT studies (Jung *et al*., 2011; Panjnoush *et al.*, 2017) This provided an important information with regards to the surgical flap when the lateral approach of the sinus lifting procedure was planned. The superficial positions of the artery towards the buccal mucosa or the sinus lining has an increased risk of intraoperative haemorrhage as a result of injury to the artery (Ella *et al*., 2008; Hong and Mun, 2011). Knowing this anatomy gives the surgeon an awareness towards the surgical design.

It is crucial to assess the vertical locations of the artery in relation to the alveolar crest and sinus floor especially in the pre-implant prosthetic surgery. This present study found a mean vertical distance between the lower border of the canal to the maxillary sinus floor to be 7.24 ± 3.84 mm which was within the range of approximately 5 mm to 11 mm found in a few other studies (Valente, 2016; Yusof *et al*., 2020). Our statistical test has

also revealed that there was a significant difference between the dentate and edentulous posterior maxilla with the edentulous group having a greater distance to the sinus floor. The sinus pneumatization towards the extracted site that occurred after extraction or loss of posterior teeth may have contributed to the greater distance of the artery to the sinus floor (Rosano *et al.*, 2010). This information is crucial in making the surgical plan of the intended amount of height for sinus lift procedure.

On the other hand, the mean vertical distance between the lower border of the canal to the alveolar crest has been reported to have wide disparities (from 11.2 to 18.1 mm) and our result has shown to be within the reported range (17.62 ± 4.72 mm) (Güncü *et al.*, 2011, Kgiku *et al.*, 2013; Rosano *et al.*, 2011). This wide variation is likely due to the variations in the residual crest height (Varela-Centelles *et al.*, 2020). In terms of dental status, this study showed no significant difference between dentate and edentulous posterior maxilla. This finding is also similar to a study by Panjnoush *et al.* in which there was also no significant difference in this distance between dentate and edentulous patients (Panjnoush *et al.*, 2017). However, in a study by Yusof *et al.*, they stated that this distance was statistically significantly lower in the edentulous posterior maxilla.

Previous literature stated that during sinus elevation procedure, the bone window height created must be at least 13 mm in order to place a 10 - 12 mm implant and the window height should not exceed 15 mm from the alveolar crest (Yusof *et al.*, 2020). This requirement is proven to be a concern in severely atrophied ridges in edentulous patients and it was evident in their study as the mean distance of the artery from the alveolar ridge in edentulous patients was 15.1 ± 3.0 mm. In our study, the mean distance obtained for edentulous patients was 19.07 ± 5.41 mm which is evidently higher than the previous report. However, this is probably due to the patients having residual ridges that have not severely resorbed yet. This can be explained by another finding in our study where the vertical distance between the maxillary sinus floor to the alveolar crest between the dentate and edentulous posterior maxilla showed no significant difference. Therefore, the assumption can be made that the majority of the edentulous patients in this study would not face a higher risk of damaging the artery while creating a bony window during sinus elevation procedure.

In similar studies, the authors found that older patients tend to have arteries with a larger diameter. However, based on the results found by Yusof and colleagues, a narrower artery was more common in edentulous patients with a mean diameter of 1.0 mm or less whereas the mean diameter of the artery in dentate patients was 1.0 mm or more (Yusof *et al.*, 2020). The mean diameter of the canal found in the current study was 1.09 ± 0.43 mm regardless of dentition and showed no statistical significance between dentate and edentulous patients. Tehranchi *et al.* reported an almost similar mean diameter of 1.29 ± 0.39 mm (Tehranchi *et al.*, 2017). Other papers reported that the mean diameter contributes significantly to the detection of the artery canal (Güncü *et al.*, 2011, Kang *et al.*, 2013, Wallace *et al.*, 2007,). The arteries observed in this study were large enough to be detected in a CBCT scan. Unfortunately, the mean diameter obtained was already entering a risky range because when an artery is larger than 1.0 - 2.5 mm, it may have a higher risk of haemorrhage. In contrast, smaller arteries with a diameter measuring less than 1.0 mm would not cause life-threatening haemorrhage if transection of the artery occurred (Güncü *et al.*, 2011, Wallace *et al.*, 2007). Despite the diameter, damage to the artery will inadvertently lead to some bleeding that may hinder the surgical access and visualisation during sinus elevation procedure which predisposes the patients to haemorrhage (Ella *et al.,* 2008; Jung *et al.*, 2011).

Conclusion

PSAA was detected in 73.5% of the cases and intraosseous PSAA being the most common horizontal position in both dentate and

edentulous patients. Dentate patients have slightly larger arteries than edentulous patients. Precautions should be taken during procedures involving the posterior maxilla as the PSAA is located less than 18 mm from the alveolar ridge with a diameter of around 1mm. These information may help surgeons in estimating the window design to avoid damaging the arterial supply during sinus augmentation and implant placement. Therefore, this study proved that preoperative evaluation of the location of PSAA in CBCT is vital to reduce the risk of intraoperative bleeding that may complicate the treatment.

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