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Prevalence of the posterior superior alveolar canal assessed with cone beam computed tomography

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PREVALENCE OF THE POSTERIOR SUPERIOR ALVEOLAR CANAL ASSESSED WITH CONE BEAM COMPUTED TOMOGRAPHY

by

Sindhura Anamali

A thesis submitted in partial fulfillment
of the requirements for the Master of
Science degree in Stomatology
in the Graduate College of
The University of Iowa

December 2012

Thesis Supervisor: Professor Axel Ruprecht

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Sindhura Anamali

has been approved by the Examining Committee
for the thesis requirement for the Master of Science
degree in Stomatology at the December 2012 graduation.

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This thesis is dedicated to my mother, father, brother and husband for their love, endless support and encouragement all through my time at Iowa.

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INTRODUCTION

Availability of sufficient bone volume is an absolute requirement for placing dental implants. In maxillary posterior regions, where bone atrophy and pneumatization of maxillary sinuses is a common sequela of tooth loss, placement of implants following a standard surgical protocol can be extremely challenging. Sinus floor elevation was first described in 1980 by Boyne & James (Boyne and James 1980) and later modified by Tatum (Tatum 1986) and Summers (Summers 1994), who introduced the transcrestal approach. Implant site development by means of sinus floor elevation has proven to be a highly predictable surgical modality for increasing bone availability in the vertical dimension and, therefore, allowing dental implant placement (Tong, et al. 1998) (Jensen, et al. 1998).

As in any other surgical intervention, a multitude of intra and postoperative complications may arise when performing sinus floor elevation procedures. One such complication is trauma to a blood vessel (Flanagan 2005) (Testori, et al. 2010). The vascular supply of the maxillary sinuses is provided by the posterior superior alveolar artery (PSA), the infraorbital artery (IOA), the greater palatine artery and the sphenopalatine artery. The PSA and the IOA are the branches of the maxillary artery that supply the lateral sinus wall and the Schneiderian membrane. Both arteries have extra and intraosseous branches, which may anastomose. The PSA runs inferiorly on the outside of the convexity of the maxillary tuberosity and lies in close proximity to the bone and the periosteum (Solar, et al. 1999) (Traxler, et al. 1999). The course of the intraosseous branch of the PSA in the buccal wall of the sinus can be either straight (78.1%) or U-shaped (21.9%) (Hur, et al. 2009). The maximum diameters of the PSA and IOA have been reported to range between 2.0 and 3.0 mm (Testori, et al. 2010) (Solar, et al. 1999). The larger the size of these blood vessels, the greater the risk of bleeding when damaged. Therefore, these vessels should be identified when planning and performing sinus floor elevation procedures due to the potential risk of intra-surgical bleeding (Ella, et al. 2008). Cone Beam Computed Tomography (CBCT) is often used for planning advanced surgical procedures, such as implant placement in the posterior maxilla. CBCT provides valuable information, including available bone (bucco-lingually and vertically), bone morphology, presence of pathological entities and location of important anatomical landmarks.

PURPOSE/OBJECTIVE OF THIS STUDY

This study is primarily aimed at determining the ability to identify the PSA in an American population using CBCT.

HYPOTHESES

1. Null hypothesis: There is no difference in the prevalence of the PSA between males and females on CBCT images.
   Alternate hypothesis: There is a difference in the prevalence of the PSA between males and females on CBCT images

2. Null hypothesis: The presence of disease in the maxillary sinus does not interfere with the examiner's ability to detect the presence of the PSA on CBCT images.
   Alternate hypothesis: The presence of disease in the maxillary sinus does interfere with the examiner's ability to detect the presence of the PSA on CBCT images.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Oral Pathology, Radiology and Medicine at The University of Iowa. Institutional Review Board approval to conduct the study was obtained. The scans used for this study were all obtained using one unit (i-CAT Next Generation, Imaging Sciences International, PA). All the scans were made at 0.4mm slice thickness with the tube current at 23.87 mA and tube voltage at 120kVp. The field of view varied depending on the area of the patients that was scanned. Only scans that met the following criteria were selected for this study.

Inclusion criteria

1. Field of view adequate to capture the maxillary sinuses
2. At least one edentulous area in the posterior maxilla (any edentulous space distal to the canine)
3. No motion artifact

Exclusion criteria

1. Prior sinus surgery and/or trauma to the walls of the sinuses. (Figures 1 and 2)
2. Diseases in the sinus (Figure 3) that caused an alteration in the morphology of the sinus walls such as displacement and/or defects in the walls of the sinus diseases. Subjects with sclerotic changes in the walls of the sinuses (Figure 4) due to sinusitis were not excluded.
3. Prior bone grafting in the region (6 subjects were excluded). (Figure 5)

All information that might allow identification of the subjects was removed from the datasets prior to evaluation. A separate database was created to store the selected scans.

Two observers, a third year oral and maxillofacial radiology resident (observer 1) and a board certified oral and maxillofacial radiologist (observer 2) were calibrated to detect the presence of the PSA. The presence of the PSA was checked in the postero-lateral wall of the maxillary sinus using coronal sections (Figure 6). The sagittal and axial images were used whenever orientation to the exact point was required. In some of the subjects who were not positioned symmetrically or if there were anatomic variations, the images were rotated to obtain appropriate parasagittal views using the tools available in the proprietary Xoran Software. Observer 1 assessed the datasets for the presence of the PSA twice on each dataset for intra-observer reliability. There was at least a one-week time period between the first and second observations. Observer 1 recorded the presence of the PSA on the left and right sides and also, at the time of the first observation, presence or absence of the following diseases: sinusitis (Figure 7), mucositis (Figure 8), mucus retention pseudocysts (Figure 9) and/or polypoid mucosal thickening (Figure 10). Observer 2 also evaluated the datasets for the presence of the PSA once. Inter-observer reliability between both examiners was calculated.

All the images were displayed on a twenty-seven inch (2560 X1440 pixels) iMac (Apple Inc., Cupertino, CA) computer, which had a 2.7 GHz Intel Core i5 processor, 12 GB DDR3 RAM, 512 AMD Radeon HD 6770 Graphics running OS X 10.8.1(Apple Inc., Cupertino, CA). The proprietary Xoran software (Xoran Technologies®, Inc. Ann Arbor, MI) running on Windows XP Professional (Microsoft®, Redmond, WA) through VMware Fusion (VMware, Inc. Palo Alto, CA) Version 5.0 in full screen mode was used for evaluating the images. The graphic display card was capable of running at full resolution on the virtual unit due to inherent hardware acceleration. In order to keep the data secure, the computer was password protected and BitLocker (Microsoft®, Redmond, WA) software was enabled in the virtual unit.

Figure 1: CBCT coronal section showing resection of the right maxillary sinus (circle)

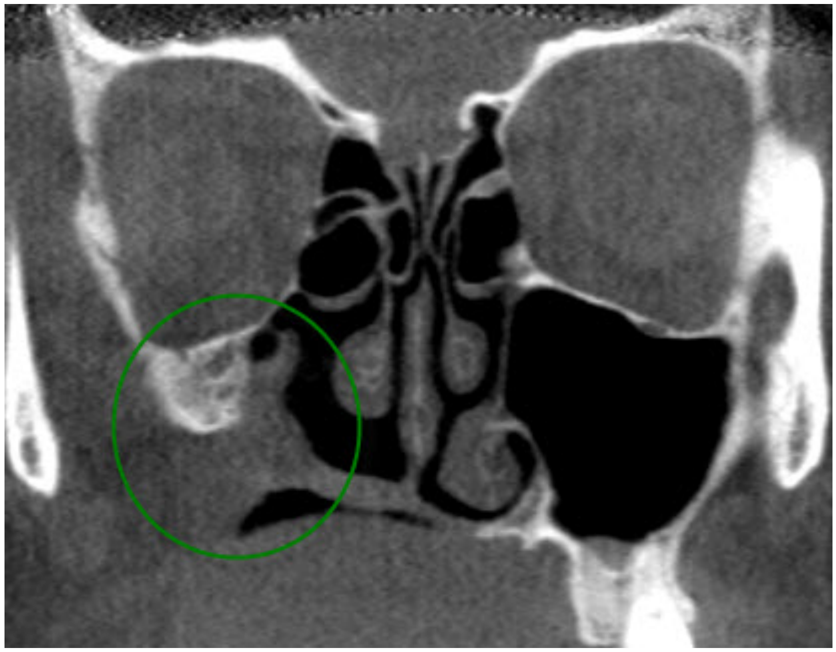


Figure 2: CBCT axial section showing resection of the right maxillary sinus (circle)

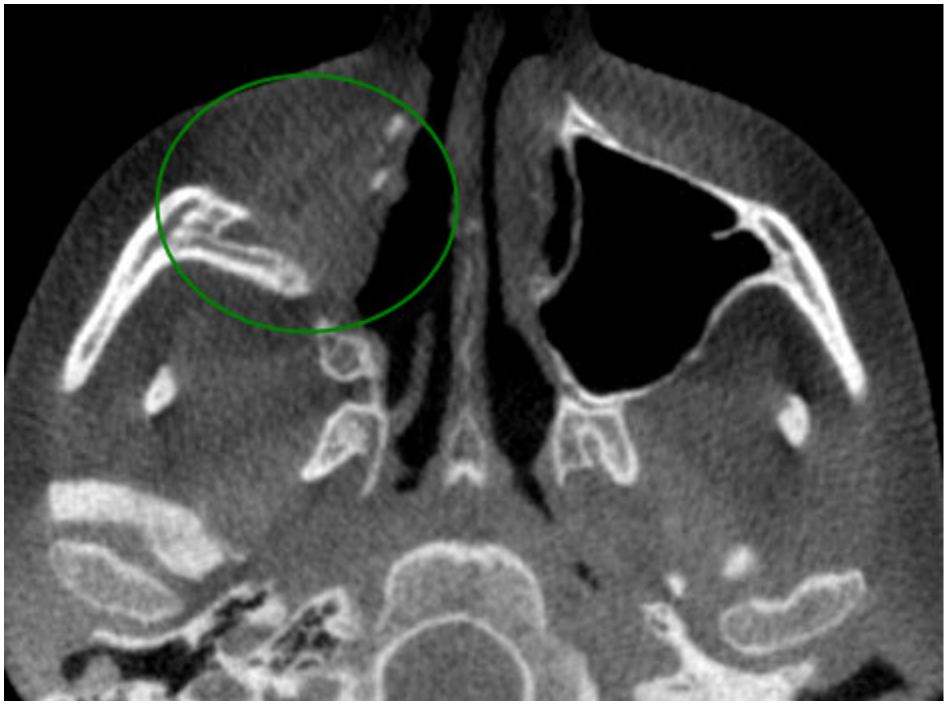


Figure 3: CBCT coronal section showing surgical changes with screws (arrows) in the left maxillary sinus

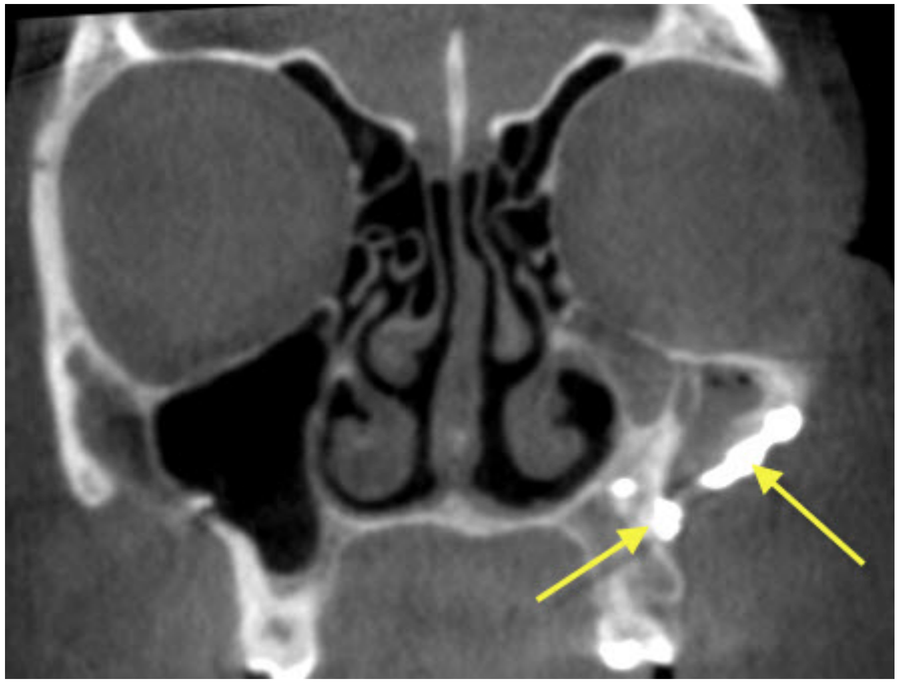


Figure 4: CBCT coronal section showing chronic sinusitis and thickening of the walls (arrows) of the right maxillary sinus

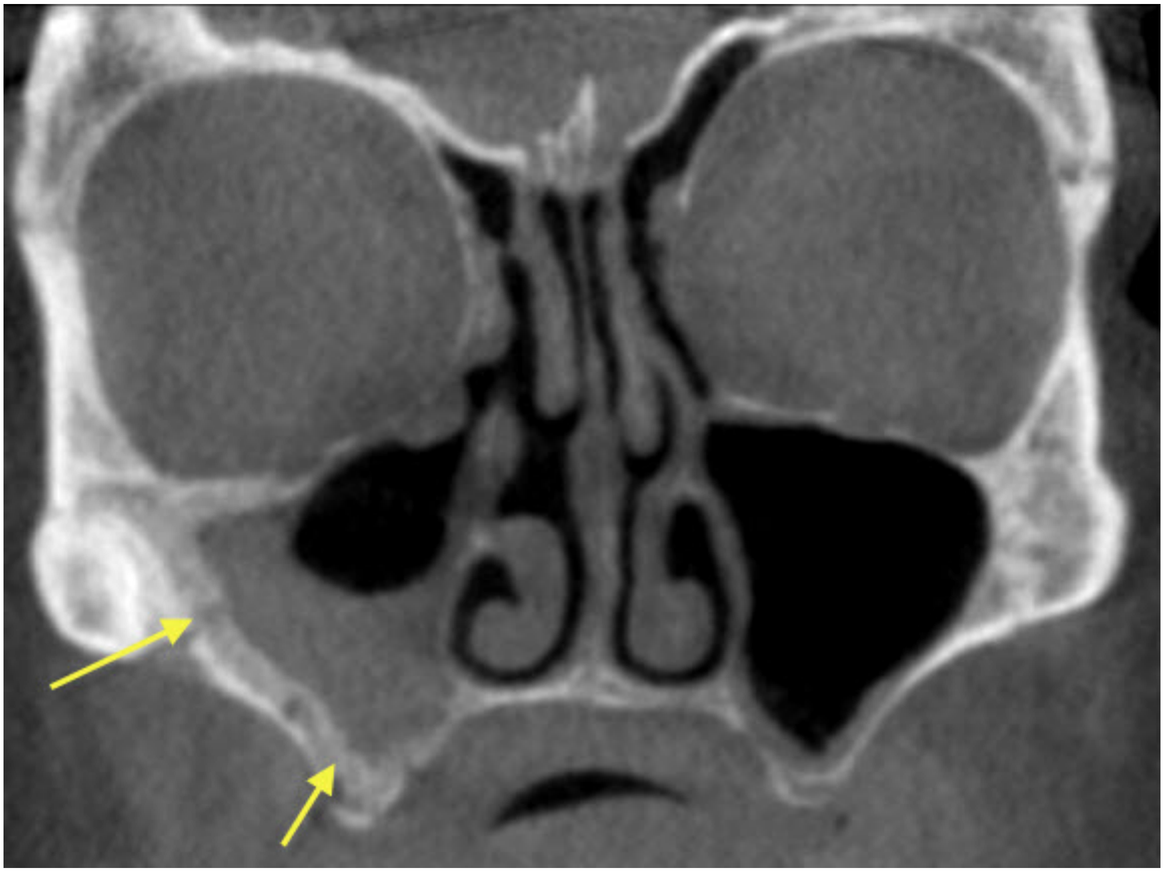


Figure 5: CBCT coronal section showing implant (yellow arrow), graft material (red arrow) and thickening of the soft tissues (green arrow) of the right maxillary sinus

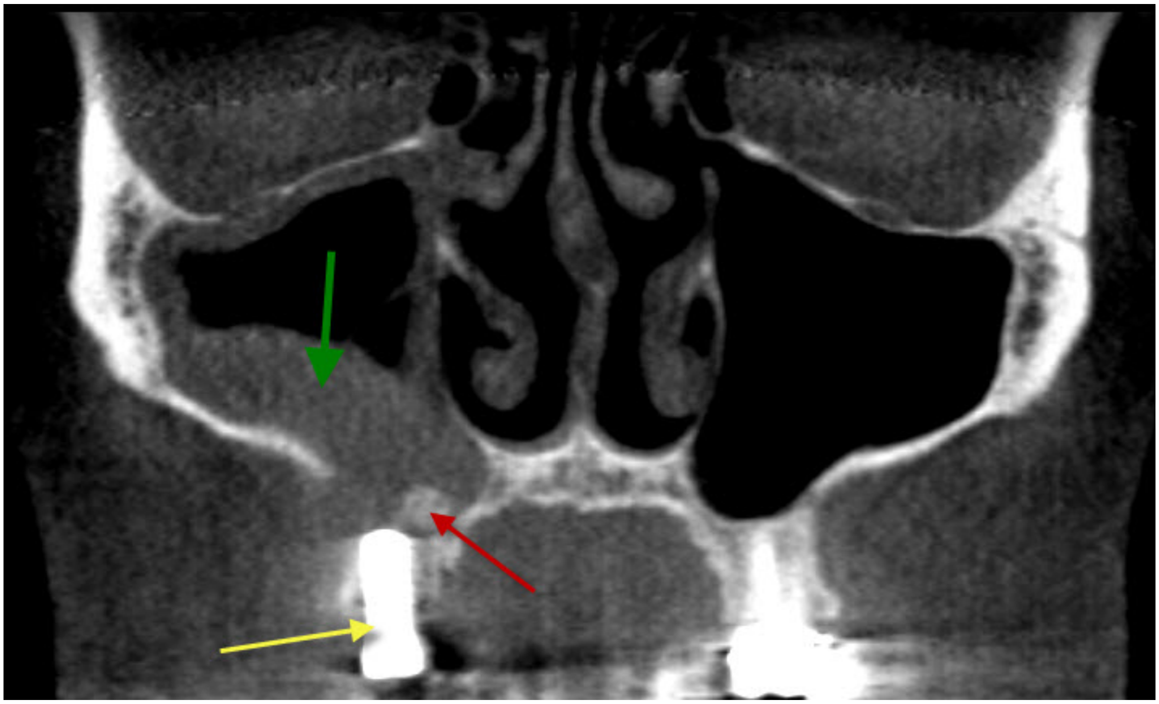


Figure 6: CBCT coronal section showing PSA bilaterally (arrows) in the wall of the maxillary sinuses

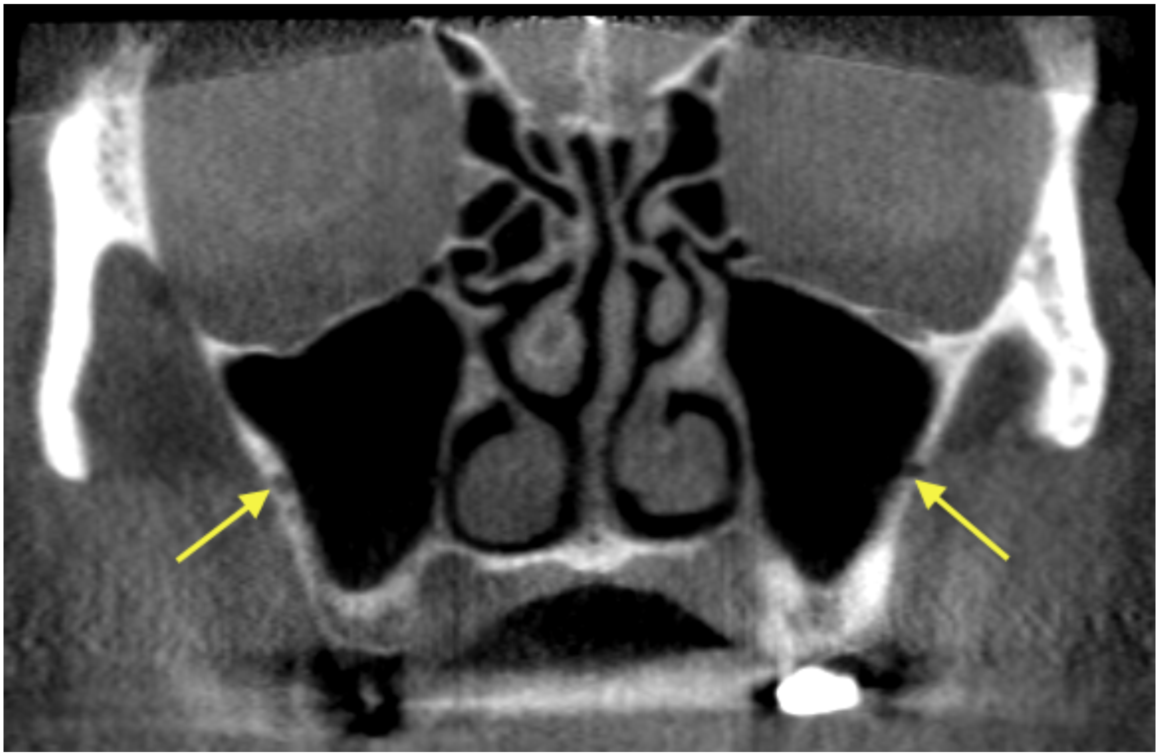


Figure 7: CBCT coronal section showing soft tissue thickening of sinusitis bilaterally (arrows) in the maxillary sinuses

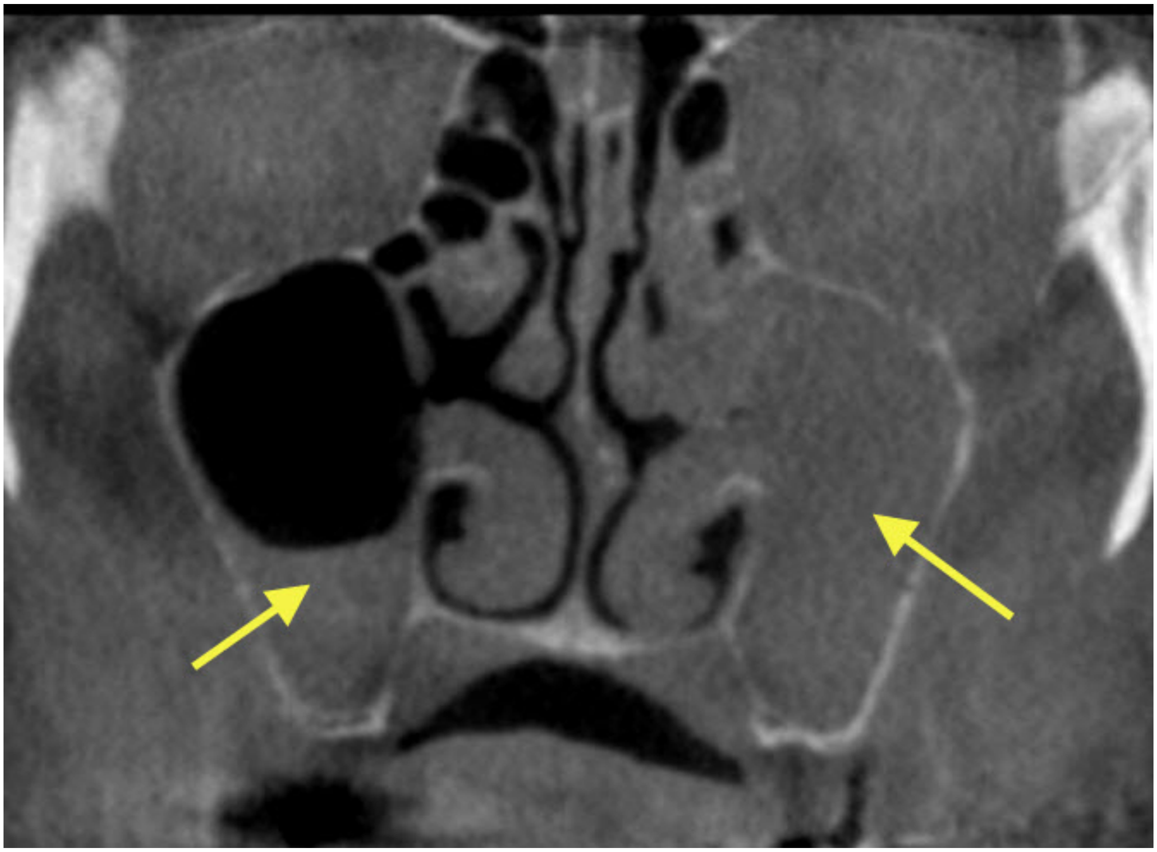


Figure 8: CBCT coronal section showing mucositis (arrow) in the right maxillary sinus

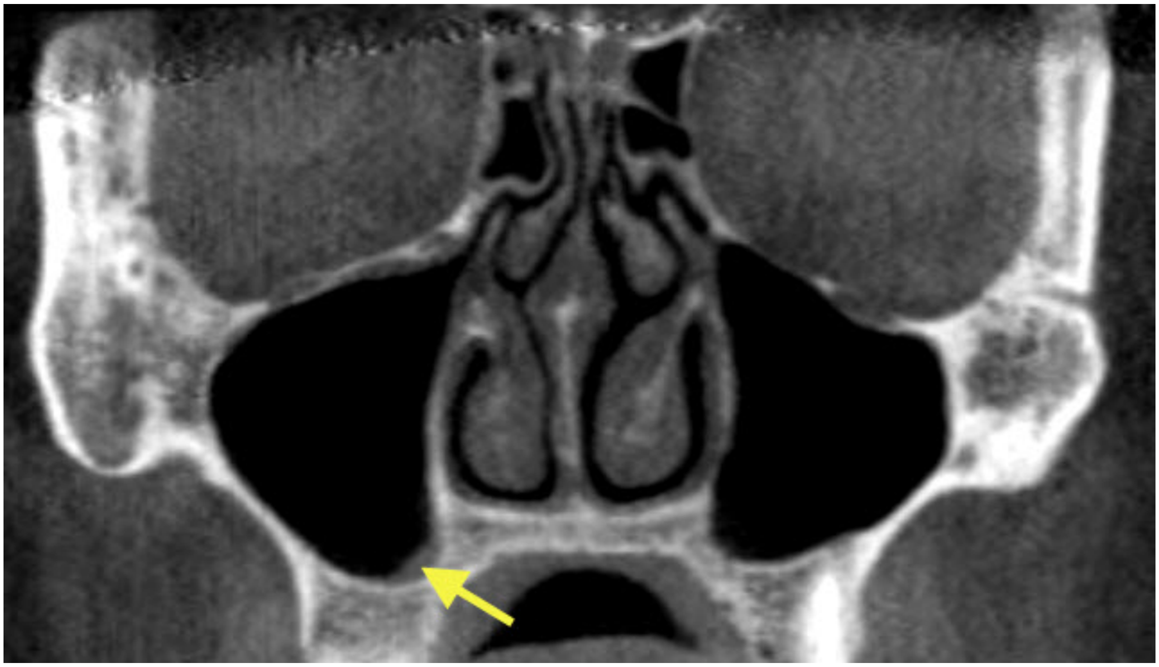


Figure 9: CBCT coronal section showing a mucus retention pseudocyst (arrow) in the right maxillary sinus

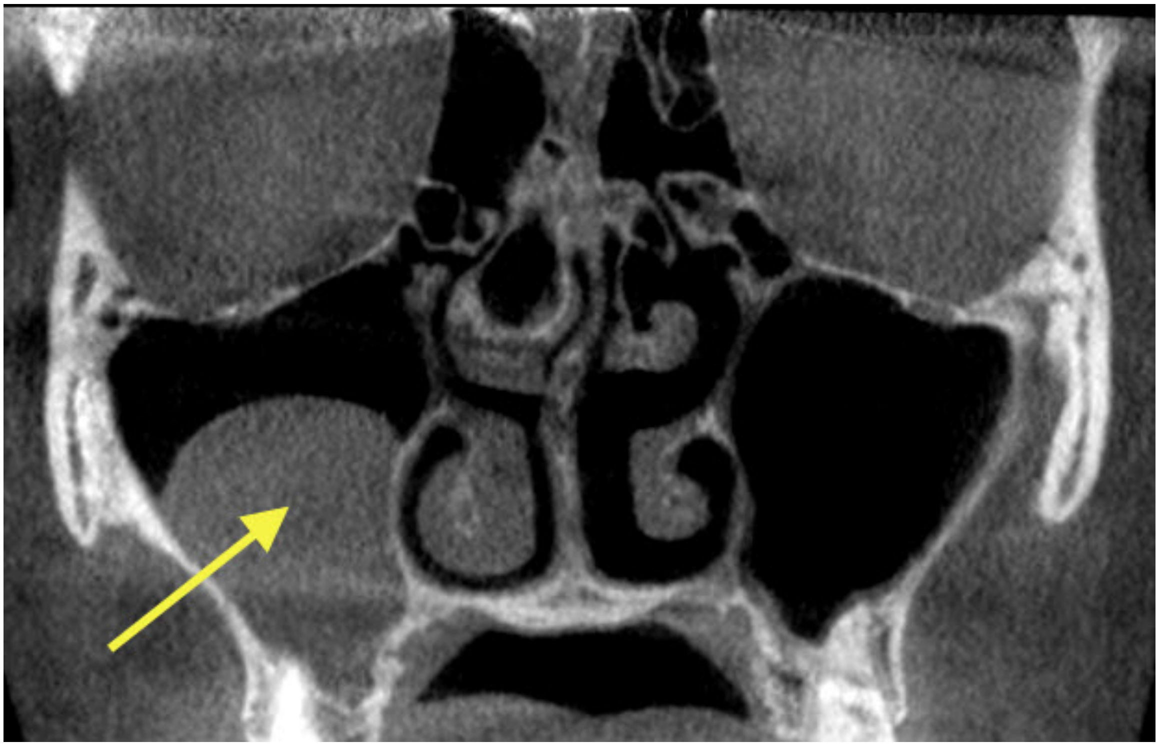
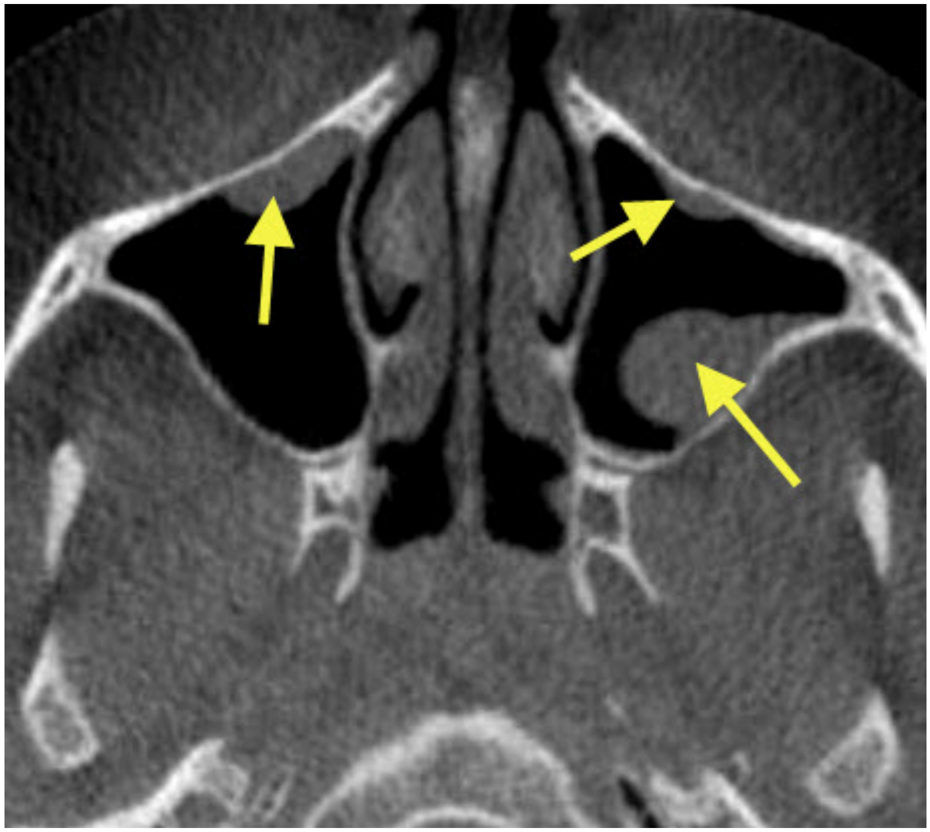


Figure 10: CBCT axial section showing a polypoid mucosal thickening (arrows) in the right and left maxillary sinuses



STATISTICAL METHODS

Descriptive statistics were conducted for all variables in the study. The chi-square test was used to determine whether there was a significant association between the sex of the subjects, presence of PSA and maxillary sinus disease. Moreover, the associations between the presence of PSA and sinus disease were evaluated for males, females and all subjects separately using chi-square test and Fisher's exact test.

Additionally, the kappa statistic was calculated to assess intra- and inter-observer agreement for the presence of PSA. The following is an approximate guide for interpreting an agreement between the two ratings (i.e. which were made on the same subject either by the same observer or by the two observers) that corresponds to kappa coefficient:

i) 0=no agreement
ii) 0.00-0.19=very poor agreement
iii) 0.20-0.39=poor agreement
iv) 0.40-0.59=moderate agreement
v) 0.60-0.79=good agreement
vi) 0.80-0.99=strong agreement
vii) 1.00=perfect agreement

A p-value of less than 0.05 was used as a criterion for statistical significance, and data analysis was completed using SAS for Windows (v9.3, SAS Institute Inc., Cary, NC, USA).

RESULTS

A total of 254 CBCT scans were selected from the departmental records for this study. One hundred and twenty males and 134 females, with an age range between 20 to 87 years (mean age 57.6 years), constituted the population of the study. Table 1 provides the descriptive statistics for all variables. However variables like ethnicity of the patients were not available since this characteristic information was not kept in the departmental records.

One subject with a residual cyst, one with a radicular cyst, two with dentigerous cysts, one with fibrous dysplasia and four with extensive surgical changes were excluded. Maxillary sinus disease (mucositis, sinusitis, mucous retention pseudocysts and/or polypoid mucosal thickening) was observed in 60 of the 254 subjects (24%) on the right side, and in 76 of the 254 subjects (30%) on the left side. In the first observation by observer 1 the PSA was seen in 237 of the subjects on the right side and 225 subjects on the left side. In the second observation by observer 1, the PSA was observed in 240 subjects on the right side and 228 subjects on the left side. Observer 2 found the PSA in 241 of the 254 subjects on the right side and in 236 subjects on the left side. The kappa coefficients of 0.83 and 0.78 indicated good or strong agreement between the two canal ratings made by the same observer on either the right or left sides. Moreover, when using the first canal ratings of observer 1, the kappa coefficients of 0.72 and 0.60 indicated good agreement between the canal ratings made by the two observers either on the right or left sides. When considering second canal ratings of observer 1, the kappa coefficients of 0.80 and 0.60 indicated strong and good agreements between the two observers either on the right or left sides.

Of the 134 female subjects, the presence of the PSA on the right side was observed in the scans of 124 and 125 subjects during the first and second observations, respectively. On the other hand, the presence of the canal on the left side was detected in the scans of 119 and 121 subjects on the first and second observations, respectively. Of the 120 male subjects, the presence of the PSA on the right side was observed in the scans of 113 and 115 subjects during the first and second observations, respectively. The presence of the PSA canal was observed in the scans of 106 and 107 subjects on the first and second observations, respectively. There was no significant statistical difference in the prevalence of the PSA between the right and left sides on both the observations.

Maxillary sinus disease was identified in the scans of 22 and 31 female subjects on the right and left sides, respectively. In males, maxillary sinus disease was seen in the scans of 38 and 45 subjects on the right and left side, respectively. The data showed that there was a significant association between the sex of the subject and presence of maxillary sinus disease on either the right or left sides, with p-values of 0.0043 and 0.0126, respectively. The results indicated that males were more likely than females to have maxillary sinus disease on the right side (63.3% vs. 36.7%) as well as on the left side (59.2% vs. 40.8%) (Table 2). However, no significant differences were found between the sex of the subjects and the presence of posterior superior canal on both the right and left sides ($p>0.05$ in instance).

Among the 22 female subjects who had sinus disease on the right side, in only two subjects did observer 1 not find the canal on both assessments. Among the 31 female subjects who had sinus disease on the left side, only in three subjects did observer 1 not find the canals in both the observations. Among the 38 male subjects who had sinus disease on the right side, only in three subjects did observer 1 not find the canal during the first observation and in only one subject during the second observation. Among the 45 male subjects who had sinus disease on the left side, only in three subjects did observer 1 not see the canal during the first observation and in only 1 subject during the second observation. Overall, among the 60 subjects who had sinus disease on the right side only, the canal was not seen in five subjects, during the first observation and in three subjects during the second observation. Among 254 subjects and among all the 76 subjects who had sinus disease on the left side the canal was not observed in six subjects during the first observation and in four subjects during the second observation. The data showed that there were no statistically significant associations between the ability of the examiner to detect PSA and maxillary sinus disease in left and right sides for male, female, and all subjects ($p>0.05$ in each instance) (Table 3 and Table 4), except for one case for males in left side (for second time observation, $p=0.03$) (Table 4).

Table 1: Summary of ALL Variables in the Study (N=254)

Variable	Frequency	Percent
Sex		
Male	120	47.2
Female	134	52.8
Maxillary Sinus Disease in the Right Side		
Yes	60	23.6
No	194	76.4
Maxillary Sinus Disease in the Left Side		
Yes	76	29.9
No	178	70.1
***First Time:**		
PSA on Right Side Observed First Time		
Yes	237	93.3
No	17	6.7
PSA on Left Side Observed First Time		
Yes	225	88.6
No	29	11.4
***Second Time:**		
PSA on Right Side Observed Second Time		
Yes	240	94.5
No	14	5.5
PSA on Left Side Observed Second Time		
Yes	228	89.8
No	26	10.2
***Second Observer**		
PSA on Right Side Observed by Observer 2		
Yes	241	94.9
No	13	5.1
PSA on Left Side Observed by Observer 2		
Yes	236	92.9
No	18	7.1

Table 2: Comparison of Presence of Posterior Superior Alveolar Canal (PSA) and Maxillary Sinus Disease between Males and Females (N=254)

Variables	**Sex**		
	Female (n=134)	**Male (n=120)**	***P*-value**
PSA in the Right Side Observed First Time			
Yes	124 (52.3%)	113 (47.7%)	
No	10 (58.8)	7 (41.2%)	0.6039
PSA in the Left Side Observed First Time			
Yes	119 (52.9%)	106 (47.1%)	
No	15 (51.7%)	14 (48.3%)	0.9059
Maxillary Sinus Disease in the Right Side			
Yes	22 (36.7%)	38 (63.3%)	
No	112 (57.7%)	82 (42.3%)	**0.0043***
Maxillary Sinus Disease in the Left Side			
Yes	31 (40.8 %)	45 (59.2%)	
No	103 (57.9%)	75 (42.1%)	**0.0126***
PSA on the Right Side Observed Second Time			
Yes	125 (52.1%)	115 (47.9%)	
No	9 (64.3)	5 (35.7%)	0.3740
PSA on the Left Side Observed Second Time			
Yes	121 (53.1%)	107 (46.9%)	
No	13 (50.0%)	13 (50.0%)	0.7664

Table 3: Association between Presence of Posterior Superior Alveolar Canal (PSA) and Sinus Disease in the Right Side

Sinus Disease on Right Side			
A. Female (N=134)			
	Yes (n=22)	**No (n=112)**	***P*-value**
PSA on the Right Side Observed First Time			
Yes	20 (16.1%)	104 (83.9%)	
No	2 (20.0%)	8 (80.0%)	0.6685
PSA on the Right Side Observed Second Time			
Yes	20 (16.0%)	105 (84.0%)	
No	2 (22.2%)	7 (77.8%)	0.6414
B. Male (N=120)			
	Yes (n=38)	**No (n=82)**	***P*-value**
PSA on the Right Side Observed First Time			
Yes	35 (31.0%)	78 (69.0%)	
No	3 (42.9%)	4 (57.1%)	0.6776
PSA on the Right Side Observed Second Time			
Yes	37 (32.2%)	78 (67.8%)	
No	1 (20.0%)	4 (80.0%)	0.9999
C. All Subjects (N=254)			
	Yes (n=60)	**No (n=194)**	***P*-value**
PSA on the Right Side Observed First Time			
Yes	55 (23.2%)	182 (76.8%)	
No	5 (29.4%)	12 (70.6%)	0.5607
PSA on the Right Side Observed Second Time			
Yes	57 (23.8%)	183 (76.2%)	
No	3 (21.4%)	11 (78.6%)	0.9999

Table 4: Association between the Presence of Posterior Superior Alveolar Canal (PSA) and Sinus Disease in the Left Side

Sinus Disease in Left Side			
A. Female (N=134)			
	Yes (n=31)	**No (n=103)**	**P-value**
PSA on the Left Side Observed First Time			
Yes	28 (23.5%)	91 (76.5%)	
No	3 (20.0%)	12 (80.0%)	0.9999
PSA on the Left Side Observed Second Time			
Yes	28 (23.1%)	93 (76.9%)	
No	3 (23.1%)	10 (76.9%)	0.9999
B. Male (N=120)			
	Yes (n=45)	**No (n=75)**	**P-value**
PSA on the Left Side Observed First Time			
Yes	42 (39.6%)	64 (60.4%)	
No	3 (21.4%)	11 (78.6%)	0.2464
PSA on the Left Side Observed Second Time			
Yes	44 (41.1%)	63 (58.9%)	
No	1 (7.7%)	12 (92.3%)	**0.0300***
C. All Subjects (N=254)			
	Yes (n=76)	**No (n=178)**	**P-value**
PSA on the Left Side Observed First Time			
Yes	70 (31.1%)	155 (68.9%)	
No	6 (20.7%)	23 (79.3%)	0.2487
PSA on the Left Side Observed Second Time			
Yes	72 (31.6%)	156 (68.4%)	
No	4 (15.4%)	22 (84.6%)	0.1135

DISCUSSION

It is important for the surgeon to have all necessary information to avoid intra-surgical and post-surgical complications. One of the more critical pieces of information for the surgeon is the location of neurovascular bundles with respect to the surgical site. Advances in imaging science have led to the ability to attain of this useful diagnostic information chair side, so that it can be incorporated in the surgical planning.

To our knowledge, this is the first study to investigate the prevalence of PSA in an American population using CBCT. A similar study was done using traditional Computed Tomography (CT) scans in a Turkish population (Güncü, et al. 2011). The prior studies (Güncü, et al. 2011) (Mardinger, et al. 2007) using traditional CT images analyzed the location, prevalence, diameter and the course of the PSA. It is important and more relevant to do such a study on CBCT, as this modality of imaging is more commonly used in North America to evaluate the morphology and volume of bone in an edentulous area prior to implant placement. Traditional CT scans require a higher dose of radiation to cover a similar field of view (Ludlow and Ivanovic 2008). In many practice settings dentists have easier access to scan patients in CBCT units than traditional CT units. Also, CBCT units are more cost effective when compared to traditional CT units. Based on this information it is more relevant to assess the morphology of anatomic landmarks like the posterior superior alveolar canal on CBCT images.

In the CBCT images used in this study it was not possible to measure the diameter of the canals consistently. Ten of the datasets used in this study were evaluated on a trial basis to measure the diameter and it was not possible to replicate the measurements accurately. Thus the study was restricted to evaluating the prevalence of the PSA canal. The investigators agreed that the size of the PSA was of minor importance compared to the location of the canal. The number of sinuses evaluated in our study, 508, is markedly greater than in prior studies, which evaluated 242 sinuses (Güncü et al.) and 208 sinuses

(Mardinger et al.), respectively. The prevalence rate of the posterior superior alveolar canal in our study was higher than in the prior studies by Güncü et al (64.5%), by Mardinger et al (55%) and by Elian et al (Elian, et al. 2005) (52.9%). The findings of this study revealed that the prevalence of the posterior superior alveolar canal (PSA) on CBCT images is high, ranging from 88.6 to 94.9% on both sides. The higher prevalence of the canals in our study may be due to the fact that the resolution is high on CBCTs when compared to the traditional CT images. Further studies need to be carried out analyzing scans generated by CBCT units from different manufacturers to confirm whether the prevalence is indeed higher on all CBCT units or it is i-CAT specific. These high prevalence values coupled with the fact that intra and inter-observer reliability was good or strong in all the observations in this study suggest that CBCT images can be used reliably for the detection of the presence or absence and location of the PSA prior to surgery for sinus lift and/or placement of implants in the region.

Our data indicated a significant association between the sex of the subjects and presence of maxillary sinus disease in both the right and left side, with p-values of 0.0043 and 0.0126, respectively. The results indicated that males were more likely than females to present signs of maxillary sinus disease on the right side (63.3% vs. 36.7%) as well as on the left side (59.2% vs. 40.8%) (Table 2). No significant differences between males and females were observed for the presence of PSA on both right and left sides ($p>0.05$ in instance), which is consistent with the first null hypothesis.

Data analysis showed that there were no statistically significant associations between the presence of PSA and maxillary sinus disease on the left and right sides for males, females, and all subjects ($p>0.05$ in each instance) (Table 3A-3B), except for one instance, males on left side (for second observation, $p=0.03$) (Table 3B), which is consistent with the second null hypothesis. Data analysis showed that there were no statistically significant associations between the presence of the PSA and maxillary sinus disease. However the observers noted that while there was no statistical difference in the study irrespective of the presence or absence of sinus disease, it was subjectively agreed amongst the observers that it was more difficult to identify the canal in the presence of disease in the sinuses, except when the sinusitis was chronic (the walls had become sclerotic and the canal was clearly visible) (Figure 6).

One of the limitations of the current study was that all the scans were from one type of CBCT unit. Future studies need to be conducted on scans from the other major CBCT units available to determine that our findings from i-CAT CBCT images are applicable to all CBCT units in general. One of the advantages of our study is that we did the study on datasets of subjects who had at least one posterior edentulous area to make it clinically more relevant when compared to the study on traditional CT images where images were randomly selected (Güncü, et al. 2011).

CONCLUSION

The PSA can be consistently visualized on i-CAT CBCT images with a high level of reproducibility. Additionally, the ability to detect the presence of the canal is not significantly affected by the presence of intrasinusal disease. There were no differences in the prevalence of the PSA on the basis of sex or side. Males present a higher prevalence of radiographic signs of maxillary sinus disease.

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