ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 3, Issue – 6, November - 2020, Page No. : 432 - 442

Evaluation of anatomical variations of Posterior superior alveolar artery and Maxillary sinus using Computed Tomography.

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Citation of this Article: Dr. Pooja Tagade, Dr. Mukta Motwani, Dr. Apurva Khator, Dr. Shruti Talmale, "Evaluation of anatomical variations of Posterior superior alveolar artery and Maxillary sinus using Computed Tomography", IJDSIR- November - 2020, Vol. – 3, Issue - 6, P. No. 432 – 442.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Introduction

Now a day, the implants are the preferred way for replacement of missing teeth. Sufficient bone quantity and quality are essential for proper dental implant placement, especially in the posterior maxilla where resorption of alveolar bone is more[1]. Implant placement in the maxilla is challenging when the maxillary sinus is extended into the alveolar ridge. Sinus augmentation is the routine surgical procedure utilized to increase the vertical height of the posterior alveolar ridge for the successful placement of dental implants[2].

Thorough knowledge of the anatomy and blood supply of the sinus is important before performing any sinus lift and bone grafting procedures[3]. The blood supply of the maxillary sinus and overlying membrane (Schneiderian membrane) basically comes from the maxillary artery. The posterior superior alveolar artery (PSAA) and infraorbital artery (IOA) are the branches of the maxillary artery that supply the lateral sinus wall and the overlying membrane[4]. During the sinus lift surgery, if PSAA get traumatized accidentally; it may cause mild to severe hemorrhage leading to perforation of the maxillary sinus membrane[5]. Variations or pathologies in the maxillary sinus can also pose difficulties during surgeries in this region. For example septa, sinusitis, cyst, polyps etc. In the presence of sinus septae, certain modification of the surgical approach will be needed in order to prevent perforation of the Schneiderian membrane and the lining of the maxillary sinus which leads to profuse bleeding during implant placement surgeries. Maxillary sinus septae can also obstruct proper visualization of the maxillary sinus and hamper the preparation of the bony window along the lateral wall of maxillary sinus during sinus floor augmentation[6,7.]

Computerized tomography (CT) is a digital imaging technique that provides three dimensional information about the sinuses and detailed information that is not available from standard radiographs[8]. It provides an accurate assessment of the craniofacial bones, extent of pneumatization of the sinuses, bone dimension, recognize specific anatomical landmarks and detect pathologies in maxillary sinus[9].

As the maxillary sinus occupies a strategic position it is connected directly to nasal cavity and related indirectly to the oral cavity and maxillary alveolus. It is therefore imperative that the oral and maxillofacial radiologist should be well versed with the normal anatomy and pathologies in maxillary sinus.

Hence, this study was conducted to evaluate anatomical variations in the vascular morphology of the posterior superior alveolar artery and maxillary sinus using computed tomography scans.

The aim of the study is to evaluate the anatomical variations of posterior superior alveolar artery and maxillary sinus using CT images. Objectives were to evaluate the location of the PSAA on lateral wall of maxillary sinus, to evaluate the relationship of PSAA with medial wall and floor of maxillary sinus, to correlate the location and diameter of PSAA according to age and gender, to evaluate and compare the anatomical variations and pathologies in maxillary sinus bilaterally.

Materials and Method

After getting approval from the Institutional ethics committee, this observational study was conducted in the Department of Oral Medicine and Radiology & Department of Radiodiagnosis. The study was carried out on 200 CT scan images of maxillary sinus (100 males and 100 females) divided into four groups according to age, each comprising of 25 males and 25 females (Group 1: 20-29 yrs, Group 2: 30-39 yrs, Group 3: 40-49 yrs,Group 4: 50-59 yrs). The CT images of head and neck region of patients above 20 years of age were observed. The CT images of patients with edentulous posterior region, patients below 20 years of age, patients with history of trauma to the maxillary sinus were not included in the study.

All CT scan images were evaluated in the coronal and axial sections for the following points:

Location of PSAA on lateral wall of maxillary sinus: (figure 1).

The location of PSAA was checked on the coronal images of the CT scan. All sections through the maxillary sinus were evaluated so as to ascertain the presence or absence of PSAA on the following locations, a.on the inner cortex, b. intraosseous ,or c. on the outer cortex

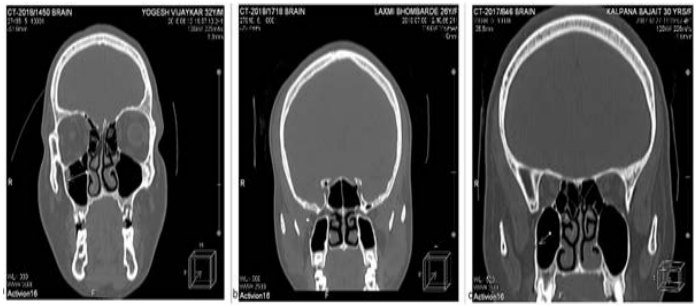

Figure 1: Location of PSAA on lateral wall of maxillary sinus. (a) inner cortex, (b) intraosseous, (c) outer cortex

Relationship of PSAA with medial wall and floor of maxillary sinus. (figure 2)

On the coronal scans, the distance between the posterior superior alveolar artery to the medial wall of maxillary sinus and the distance between the posterior superior alveolar artery to the floor of maxillary sinus was measured with the help of linear sliding caliper measurement tool.

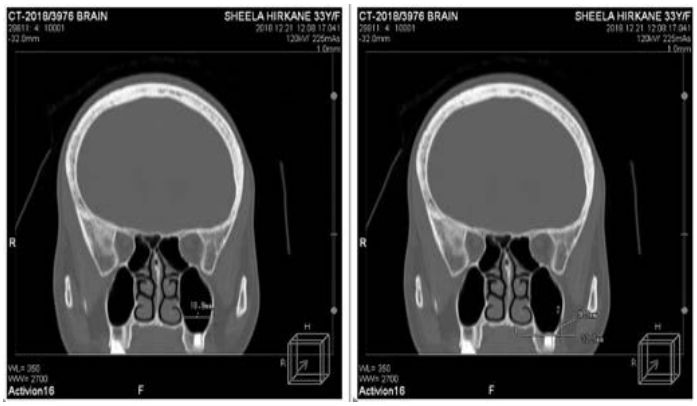

Figure 2: Relationship of PSAA with (a)medial wall and (b)floor of maxillary sinus

The diameter of PSAA (figure 3). The diameter of the posterior superior alveolar artery on the lateral wall of maxillary sinus was measured using linear measurement tool on CT scan in following groups: (a) < 1 mm, (b) 1–2 mm, and (c) > 2 mm.

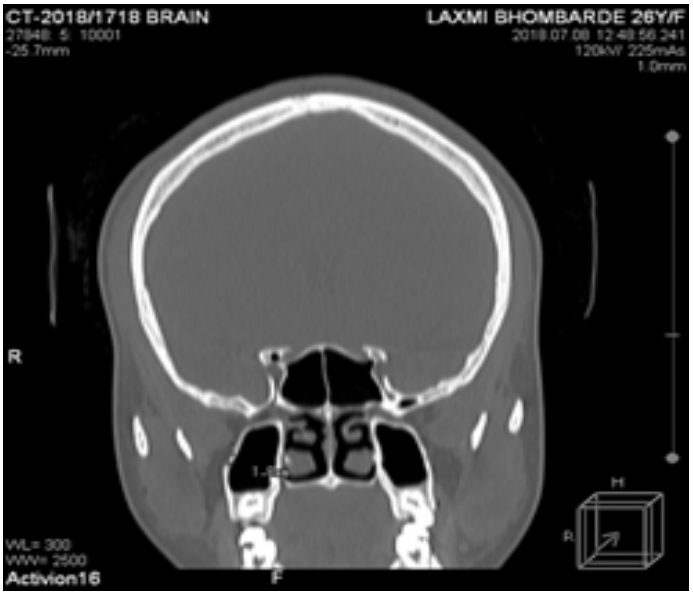

Figure 3: The diameter of PSAA

Anatomical variations of maxillary sinus: Area of maxillary sinus, volume, septa, thickness of mucosal lining, any pathologies like sinusitis, polyps, cyst, opacification, etc. was recorded. (figure4,5).

Figure 4: Measurements of maxillary sinus on (a)coronal section and (b)axial section

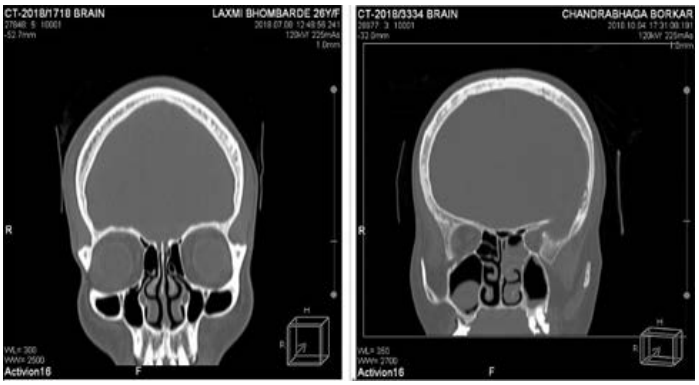

Figure 5: pathologies, (a)septae seen on right and left maxillary sinus(MS) and (b)polyp on right MS, (b) mucositis on left MS

Area was measured in coronal section by taking the maximum value of craniocaudal and transverse distance while volume was was measured in coronal and axial section by taking the maximum value of craniocaudal, transverse and anteroposterior distance.

Area of the maxillary sinus was calculated by:

Area = (craniocaudal distance x transverse distance) mm^2.

The volume of the sinus was calculated by:

Volume = (height x length x width x 0.5)mm^3

Anatomic variations

The CT scans were also evaluated for anatomic variations like septas as they pose difficulties during surgeries in this region.

Septae: Septae seen in the maxillary sinus may be unilateral or bilateral or both. Septae can be seen in many patterns like complete horizontal, partial horizontal, complete perpendicular, partial perpendicular, single of multiple(2 or 3)[1]

Pathologies of maxillary sinus: The sinuses were also evaluated for the presence of any pathologies in the maxillary sinus like mucosal thickening(mucositis), polyps, sinusitis.

Mucosal thickening: Thickening of more than 1 mm in any wall of the maxilla.

Polypoid lesions: Homogenous round opacities with distinct demarcating boundaries at the base of the maxillary sinus.

Complete opacification: Completely opacified maxillary sinus in all axial and coronal slices suggestive of maxillary sinusitis[4,10.]

Data Analysis

The real scale data generated on various parameters was compared using parametric tests like Student's t- test, one-way ANOVA. The significance level was set at 5% and the analyses was performed using SPSS 20.0 (SPSS Inc.)

Results

In this study, PSA artery was found in 86 (21.5%) maxillary sinuses in which intraosseous location (55.8%) was the most commonly found followed by outer cortex (22.5%) and the inner cortex (18.6%). Out of the 86 arteries, PSAA was found in 57(66.28%) cases and 29 (33.7%) cases in males and females respectively. (Table 1)

Table 1: showing overall distribution of location of PSAA in males and females.

Location	Total Frequency	Males	Females
Inner cortex	16(18%)	11	5
Intraosseous	48(55.6%)	29	19
Outer cortex	22(25.5%)	17	5
Total present	86(21.5%)	57(66.28%)	29(33.72%)
*P value	0.94 (NS)	0.013 (S)	0.014 (S)

(*p value obtained using one way ANOVA test. NS- not significant, S- significant at 5% level of significance.)

The average distance of PSAA from the medial wall was 13.34±4.5mm while the distance of PSAA to floor was 13±7.06mm. As the p-values were (0.99>0.05) and (0.074>0.05), there was no significant difference between the distance of PSAA from medial wall and from the floor respectively among different age groups. For male patients there was no significant difference between distance of PSAA to medial wall and floor according to right and left sides. For females patients, there was no significant difference between distance of PSAA to medial wall according to right and left side whereas there was significant difference between distance of PSAA to floor according to sides(p-value(0.024<0.05) on right side and (0.013<0.05) on left side).(Table 2)

Table 2: showing overall distance of PSAA to medial wall and floor in males and females.

	(mm)	Medial Wall	P Value	Floor	*P Value
Overall		13.34±4.5	*0.992(NS)	13±7.06	*0.074(NS)
Males	**Right**	14.35±3.43	*0.35(NS)	13.38±7.73	*0.062(NS)
	Left	15.106±4.09	*0.07(NS)	14.60±7.72	*0.056(NS)
Females	**Right**	13.2±1.2	*0.058(NS)	7.2±3.3	*0.024(S)
	Left	13.5±0.12	*0.13(NS)	13.59±3.5	*0.013(S)

(*p-values obtained using one way CHI SQUARE test at 5% level of significance, Ssignificant,

NS- not significant)

The mean diameter of PSAA was 1.460±0.27mm. In group I and II there was significant difference in the mean variations of diameters <1mm, 1-2mm and >2mm [pvalue(0.021<0.05) and (0.013<0.05)] whereas there was no significant difference among different range of diameters in group III and IV. Overall 7(8.13%) of patients had PSAA with diameter < 1mm and 69(80.23%) of patients had PSAA with diameter 1-2mm. 10(11.62%) of patients had PSAA with diameter >2mm. (Table 3)

Table 3: showing diameter of PSAA in different age groups.

Groups	<1mm 7(8.13%)	1-2mm 69(80.23%)	>2mm 10(11.62%)	*P Value
I	1.09±0.41	1.61±0.28	2.125±0.125	0.021(S)
II	0.75±0.07	1.55±0.29	2.466±0.288	0.013(S)
III	1.2±0.43	1.51±1.23	NA	0.139(NS)
IV	NA	1.55±0.28	1.86±0.263	0.26(NS)
Total Mean	1.460±0.27mm			

*p-values obtained using one way CHI SQUARE test at 5% level of significance, S significant,

NS- not significant, NA- not available

Overall mean area and volume of maxillary sinus (MS) was 666.3 ± 235.81mm^2 and 11966.5 ± 5188.34mm^3 respectively. There was no significant difference between area of PSAA for different age groups [P-value was (0.92>0.05)]. In all the groups p value was<0.05 which suggests that there was a significant difference between the areas of males and females. In age group I and II there was significant difference in the volume, while in age group III and IV there was no significant difference in the volume of MS according to gender.(p value <0.05, p value >0.05 respectively). (Table 4)

Table 4: showing area and volume of maxillary sinus in different age groups in males and females.

Groups	Area (mm)^2		*P Value	Volume(mm)^3		*P Value
	Males	Females		Males	Females	
I	1123.20 + 2318.03	708.03 + 203.40	0.025 (S)	15165.94 + 6141.53	12850.82 + 4400.01	0.034(S)
II	792.14 + 239.10	718.28 + 214.76	0.013 (S)	14828.36 + 5388	12812.47 + 4633.09	0.024(S)
III	777.19 + 271.44	687.57 + 218.29	0.039 (S)	13853.2 + 6878.14	12089.57 + 4049.11	0.16 (NS)
IV	687.85 + 274.72	649.07 + 189.31	0.021 (S)	12340.74 + 6176.5	11678.9 + 3979.85	0.42 (NS)
Total	666.3 ± 235.81		0.92 (NS)	11966.5 ± 5188.34		0.34 (NS)

*P value is obtained using CHI SQUARE test at 5% level of significance. S- significant, NS not

Significant

Out of 400 maxillary sinuses, 190(47.5%) maxillary sinuses had septa. 93(48.95%) septae were present on the right side, and 97(51.05%) septae were present on the left side. The number of septae on the right and left side were insignificant in particular age groups. 93(46.5%) maxillary sinuses had septa in male patients and 97(48.5%) septae were present in female patients. (Table 5)

Table 5: Shows number of septae in males and females among different age groups.

	Sides	Groups	Males	Females
Total 190(47.5%)	Right 93(48.95%) *0.07NS	I	14	10
		II	12	10
		III	12	10
		IV	15	10
	Left 97(51.05%) *0.06NS	I	8	16
		II	12	15
		III	14	12
		IV	6	14

*P value obtained using CHI SQUARE test, at 5% level of significance. NS- not significant

Pathologies were seen in 159(39.75%) maxillary sinuses out of 400. Maximum pathologies were present in group III (55). In group I, 31 pathologies were present, in group II and group IV 35 and 38 pathologies were present respectively. 101(63 %) mucositis cases were present. Polyp 22(13.83%)were fewer as compared to mucositis and sinusitis 36(22.64%). According to age group, there was insignificant difference between all the pathologies (p-value0.06>0.05). P-value was (0.0006) for males and 0.002 for females hence, there was significant difference between different pathologies. (Table 6)

Table 6: shows total number of pathologies in different age groups and in males and females

Groups	Mucositis	Sinusitis	Polyp
I	15	13	3
II	22	4	9
III	40	9	5
IV	23	10	5
Total *0.06NS	101	36	159(39.75%)
Males 99(*0.0006 S)	70	20	9
Females 60(*0.002 S)	31	16	13

*P value obtained using one way ANOVA at 1 % level of significance. S- significant NS- not significant

Discussion

The blood supply of the maxillary sinus is by three arteries namely, infraorbital artery (IOA), posterior superior alveolar artery (PSAA) and anterior superior alveolar artery. The introsseous branch of PSAA supplies the maxillary molar and maxillary sinus[11]. Since the maxillary sinus has a complex location and a rich blood supply it is very crucial to investigate it to avoid complications during and after surgeries which are discussed as under.

During the sinus lift surgery if PSAA gets traumatized accidentally, it may cause mild to severe bleeding, obscuring the vision of the operator and May also lead to perforation of the maxillary sinus membrane6. As the posterior superior alveolar nerve lies in close proximity to the PSAA, there is a high risk of pain, inflammation or ischemia during or after the treatment[12]. While performing Le Fort I osteotomy, the osteotomy line is generally placed at the higher level that is 4 to 5mm above the root apex of maxillary molar. In such situation also there can be a possibility of risk of injury to PSAA during osteotomy leading to nasal bleeding[11,12].

The artery may also be damaged during procedures like orthognathic surgeries, removal of pathologic lesions and infections of the maxillary sinus, post-operative membrane perforations, bone necrosis, Lefort I fracture treatment and Caldwell-Luc surgeries[12,13,14]. While giving PSA nerve block, due to incorrect injection technique there may be a hematoma formation which makes assessment of PSAA and PSAN vital [12]. Since these surgeries are routinely carried out these days, it is very important for the oral surgeons to take precautions not to damage the extensive blood supply of maxillary sinus specially the PSAA.

Due to the disadvantages like superimposition of images and limited total visualization of the sinus, one should not rely upon them as a guide for the diagnosis and treatment. With the advent of newer imaging modalities like Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT) it has been possible to obtain both two dimensional and three dimensional images. The following study was done using CT scan as larger field of view is available, therefore maxillary sinus evaluation can be done and bilateral comparison is possible.

In this study, when CT images of 400 maxillary sinuses were evaluated the PSAA could be visualized in 86 maxillary sinus that is in 21.5% of cases. The images were evaluated in coronal sections at 1.0mm slice thickness. Previous studies done on CT imaging have found success rate of identification to be 54% to 74% [1,2,5,15]. Whereas in studies done on CBCT a higher success rate can be seen [4,16,17,18]. The difference in the prevalence and location of PSAA may be due to the differences in the sample size or the methodology of the other studies. According to solar et al, in their study they demonstrated that there is anastomosis between PSAA and IOA which was found in 100% of cadaveric specimen. This suggests that not detecting PSAA on CT scans does not necessarily mean that the artery is missing or absent. It may be due to its small diameter that goes unnoticed. Another reason could

be that the studies conducted on CBCT could better identify PSAA's because of their high resolution images.

Intraosseous location (55.8%) of PSAA was the most commonly found followed by outer cortex (25.5%) and the inner cortex (18.6%).Similarly intraosseus location of PSAA was predominantly found by many authors [1,3,4,12,15,17]. Whereas the inner cortex location of PSAA was found only in two studies by Khojastehpour et al[16] (49.8%) and Haghanifer et al[14](49.7%) which is in contrast with the present study. This artery could be located predominantly in males(66.28%) as compared to females (33.72%) which was highly significant. Kurt et al[19],Park et al[10], Khojastehpour et al[16] had similar findings in their studies. In contrast to our findings a study conducted by Shahidi et al[17] showed more incidence of PSAA in females(65.7%). The difference of incidence of PSAA among male and female may be due to the difference in the male to female ratio and also the racial differences in the study population.

If the approximate distance of the PSAA from the floor and the medial wall is known, surgeries in this region can be planned in such a way that it does not get traumatized. The PSA artery was detected at a mean distance of 13.34±4.5mm from the medial wall of maxillary sinus. According to Guncu et al[1] the mean distance of PSAA from the medial wall was 11±3.8mm in their study. The difference in the mean could be due to different sample size by different authors.

Mean distance of PSAA from floor was 13±7.06mm which is almost similar to the findings of Kurt et al[19] (13.2mm). Haghanifer et al[14] reported the distance of artery to the floor and medial wall increased from first premolar to third molar teeth, ranging from 5.64mm to 9.75mm and 4.3mm to 9.55mm respectively while Hur et al[11] reported distance of PSAA to floor for dental areas were 9.4,9.7,10.3,9.6 and 9.5mm for first premolar to third molar teeth. This difference could be due to measuring the distance at five dental areas in the course of the artery. The results would possibly also change, if they are compared in dentate and edentulous patients.

Studies have also measured the distance from PSAA to alveolar crest, but this distance will vary due to the crestal bone loss, presence or absence of teeth and periodontal pathologic condition[12,19].

In the present study, there was statistically insignificant difference between the distance of PSAA to medial wall and floor of maxillary sinus with age. According to Haghanifer et al[14] and Ilguy et al[4] as the age increases distance of artery to medial wall decreases which is in contrast with the present study. These differences could be explained by the anatomic variation in the positions of arteries as they have examined the location of PSAA in different locations from first premolar to third molar. Other reason could be due to the small number of cases evaluated by these authors.

Damage to the bony canal can cause bleeding at the site of operation which may obscure the vision causing membrane perforation which prolongs the operation and assessment of the sinus membrane reflextion. The incidence of intense bleeding during sinus augmentation procedures, osteotomy and pathologies in maxilla is low when the diameter of PSAA is small[4]. The possibility of having surgical complications is more in larger canals and it should be taken into account before performing surgeries[3].

The mean diameter of the PSAA was found to be 1.460±0.27mm. Out of 86 arteries located, 8.13% of the arteries were <1mm, 11.62% of the arteries were >2mm and 80.23% of the arteries were 1-2mm. In the study conducted by Guncu et al[1] and Kim et al[20] the mean diameter was 1.3±0.5mm and 1.52±0.47mm respectively which is almost similar to the present study. However

Ibrahim et al[15], Ilguy et al[4] and Haghanifer et al[14] reported mean diameter to be less as compared to the present study (1.15±0.38mm, 0.94±0.26mm and 0.91±0.31mm respectively). Similarly studies conducted by Guncu et al[1] and Tehranchi et al[18] found that 51.4% and 74.8% of arteries measured between 1-2mm. Whereas in the studies conducted by Hayek et al[3], Ilguy et al[4]and Haghanifer et al[14] diameter less than 1mm found in 68.1%, 68.9% and 69.81% respectively.

These differences in the diameter in different studies can be attributed to the use of CBCT which has high resolution and hence has the ability to detect even very small diameters of blood vessels (0.3mm) [14]. Another reason may be attributed to racial differences in the study population.

In the present study, total average area of the maxillary sinus was 6.66 ± 2.35cm^2 and the volume was 11.96 ± 5.18 cm ^{3}. In the studies conducted by Kanthem et al[8] , Ariji et al[21],Ariji et al[22] , Attia et al[23], Bangi et al[24] where they found larger area (8.5 to 10.2cm^2) and volume (14cm^3 to 31cm^3) of maxillary sinus. This discrepancy may be due to different geographical population used sample size collection and different methods of calculating the dimensions. The data which was automatically computed were14-17% higher than the manually calculated volume38.

There is no significant difference between area and volume of maxillary sinus in different age groups.(P-value 0.92>0.05, P-value 0.34>0.05). However according to Ariji et al[21]and Ozdikici et al[25] there was statistically significant difference among age groups, in which as age increased size of the maxillary sinus decreased. After birth, the maxillary sinus continues to pneumatize into the developing alveolar ridge as the permanent teeth erupt. At the age of 20 years with the completion of the eruption of third molars , pneumatization of sinus ends. The change in adult maxillary sinus volume with age is thought to be related to the presence or absence of posterior maxillary teeth[26].

The area of the maxillary sinus was significantly more in males as compared to females. This was in accordance with the studies conducted by several Indian authors[8,18,27]. Whereas no significant difference was seen between males and females in the studies conducted by Ariji et al[22], Attia et al[23]and Ozdikici et al[25]. This could be due to population variation as our study was carried out in Indian population.

Other complications that may interfere while performing surgeries are the anatomical variations of maxillary sinus which includes septas. Due to presence of septa, during the maxillary sinsus surgeries it can obstruct the proper visualization of the maxillary cavity so there are chances of membrane perforation[7].

In the present study, out of 400 maxillary sinus,190(47.5%)sinuses showed septas. Whereas in the studies conducted by Bornstein et al[28], Sigaroudi etal[29] , Orhan et al[30] septas were found in the range of 55% to 69%. This difference could be due to the thickness of the imaging slice, septae may be missed if the slice thickness is more. Overall maxillary sinuses of 97 (48.5%) females and 93(46.5%) males had septa which is almost equal for both the genders.

Whereas male predilection was seen in the study conducted by Ilavenil et al[6] (54.5% males, 45.4% females) and female predilection were seen in the study conducted by Sigaroudi et al[29] (61.2% females, 38.8% males). This variation may be due to the different methodology used and variations in sample size and population.

In the present study, the number of maxillary sinus having septas were independent of the age group similar results were obtained by Orhan et al[30]. When compared among right and left, 93 septas (48.95%) were on right side while

97 septas (51.05 %) were on left side. This is in accordance with other studies who also did not find any significant difference between right and left[6,28,30].

While viewing the maxillary sinuses one should look for other incidental findings like mucosal thickening, opacification, polypoid mass, neoplasms, etc should be viewed in the imaging field.For dental implant siteassessment in the maxilla, the configuration and status of themaxillary sinus is important to assess the available amount ofbone. If a sinus lift is indicated, the visualization is useful,because the success rate of sinus lift procedures is cruciallydependent on the configuration and status of the maxillarysinus.Hence, in order to avoid unnecessary treatment or provide appropriate treatment planning and follow-up, the significanceof incidental pathologic findings should be clarified[31,32].

Out of all the pathologies,mucositis was the most commonly seen 101(63.52%) followed by sinusitis 36(22.64%) and polyp 22(13.83%). These results were in accordance with the studies conducted by several authors where mucositis were found maximally[31,32]. The variation in the results may be due the slice thickness of 1 mm which was used in our study, this could also have influenced the high occurrence of mucosal thickening in our study.

Maxillary sinus pathologies did not show predilection for any particular age group (P value is 0.06>0.05). The studies conducted by Raghav et al[32], Lim et al[33] also had the similar results. No significance of age could be due to the fact that the patients varied in age from 20 to 59 years of age and did not include patients under 12-years of age. The formation of their MS is still incomplete and certain abnormalities such as mucosal thickening and opacification are common findings in early childhood[34].

Conclusion

Preoperative imaging of the maxillary sinus is helpful for the assessment of location of PSAA, its distance from the medial and floor of maxillary sinus, morphology of maxillary sinus and anatomical variations. These may be used to adjust the surgical treatment plan to yield more successful treatments and avoid possible complications.

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