Original Article

Anatomic variations of the osteomeatal complex and its relationship to patency of the maxillary ostium: A retrospective evaluation of cone-beam computed tomography and its implications for sinus augmentation

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Abstract

Aim: The aim of this study is to determine the incidence of obliterated osteomeatal complex (OMC) due to the presence of anatomic variants.

Settings and Design: Retrospective Study.

Materials and Methods: In this retrospective study, a total of 71 patients, 34 males and 37 females, aged 35–65 years were included in the study. Cone beam computed tomography (CBCT) scans of patients were assessed to identify the status of the OMC in the presence of anatomic variants and their incidence was recorded. The radiological assessment of the anatomical variants was made by viewing the coronal sections of the scans. The variants observed were deviated nasal septum, uncinate process), agger nasi, Haller cells, middle turbinate variants, enlarged bulla, accessory ostium, and maxillary sinus abnormalities). Ostium patency was evaluated in the coronal section of each sinus and classified as "patent" or "obstructed." The most common variants observed were then correlated with the patency of the ostium.

Statistical Analysis Used: Chi square test was performed to assess the association between the anatomic variants and the patency of the OMC.

Results: In the present study, the incidence of an obliterated OMC due to the presence of anatomic variants was 73.2%. The four most common variants associated with the possibility of an obliterated OMC were the deviated nasal septum (76.2%), middle turbinate (86.4%), enlarged bulla (77.8%), and sinus cavity variants (80.0%). A statistically significant association was noted between middle turbinate variants and Haller cells and the patency of the OMC.

Conclusion: Thorough pretreatment CBCT evaluation should be performed to assess the presence of anatomic variants and thereby, the patency of the ostium before sinus floor elevation procedures. The pre and postsurgical treatment plans and regimes can be modified according to anticipated postsurgical sequelae, thereby avoiding postsurgical complications and enhancing the success of the graft procedure.

Keywords: Dental implants, diagnostic imaging, sinus floor augmentation

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INTRODUCTION

Atrophy of the maxillary alveolus and pneumatization of the maxillary sinus following extraction of the maxillary posterior teeth is a common finding.[1] Such clinical situations necessitate sinus floor elevation procedures for increasing the bone height in the posterior maxilla before implant placement. The maxillary sinus graft procedure is predictable and reliable, as are the implants placed into the graft.[2,3]

Thorough preoperative evaluation of the maxillary sinus is necessary before sinus augmentation procedures. The elevation of the sinus membrane is known to cause swelling and inflammation of the sinus mucosa. Patients with a history of sinusitis are prone to failure of the graft procedure and are thus a relative contraindication for sinus augmentation procedures.[4,5] Careful evaluation of a patent osteomeatal complex (OMC) is essential for the survival of any graft placed in the sinus cavity before sinus elevation procedures.[5]

The ostium is the exclusive pathway for maxillary secretions to escape into the middle meatus. Ostium patency, impaired epithelial function, or altered nasal secretions are some of the related pathophysiologic features of underlying maxillary sinus disease.[6] The anatomic variations such as a hyperplastic uncinate process, concha bullosa, maxillary ostium stenosis, septal deviations or nasal polyposis cause impaired maxillary sinus drainage and reduced ciliary activity. This leads to decreased oxygen and increased carbon dioxide concentrations. It is followed by epithelial dysfunction, which predisposes to infections causing edema and mucosal hypertrophy of OMC, with deterioration in sinus ventilation and drainage.[7]

The presence of anatomic variants of the OMC is a common finding, and at the same time, the patency of the ostium is significant during sinus floor elevation procedures. Literature has reported that anatomic variants of the OMC may occur in a population ranging from 67% to 83.5%, with the highest degree of variability seen for the nasal septum followed by the middle nasal concha, uncinate process, and other sites.[8] The incidences of these variants have been studied in the past. Studies evaluating the correlation between the anatomic variants and the patency of the OMC are scarce in the literature.

The objectives of the present study were: (i) to determine the incidence of the most common anatomic variations of the OMC in a cross-section of cone-beam computed tomography (CBCT) scans, (ii) to observe the status of the OMC and determine the incidence of its obliteration in the presence of these individual anatomic variations, and (iii) to determine which anatomic variations when occurring in tandem would most likely be associated with an obliterated OMC.

MATERIALS AND METHODS

Study design and recruitment

This retrospective observational study included 71 patients, 34 males and 37 females, aged 35–65 years (mean age 43.36 ± 12.5 years). The CBCT scans recorded between January 2015 and June 2015 from the database of the implantology department of M. A. Rangoonwala Dental College and Research Center were included in the study. The study was conducted after the approval of the Institutional Review Board (Adm/7504-A/2015). Patients with >1 missing maxillary posterior teeth (right or left side) and undergoing scans for implant surgery were included in the study. Patients with any major disease contraindicative of implant surgery, history of head and neck radiotherapy, chemotherapy, uncontrolled periodontal disease, and sinuses showing the presence of biomaterial due to augmentation were excluded from the study. In addition, the scans showing evidence of implant placement and the scans that did not allow visualization of the maxillary sinus and the OMC were excluded from the study.

The sample size was determined using the formula: $4pq/L2$

Prevalence of anatomical variation of 65% was considered for OMC with a confidence interval of 95%. Considering the error of 20%, the sample size was arrived at 70 patients based on the findings of Aramani *et al*.[9]

Evaluation of cone beam computed tomography scans

The CBCT images were obtained using the i-CAT 3D Imaging system (Imaging Sciences International, Hatfield, PA, USA). Operating parameters were as follows: 5–7 mA, 80 kV, field of view: 6 cm × 6 cm or 8 cm × 8 cm, voxel size: 0.25 mm and scan time: 20 s as. The software provided with images in the axial, coronal and sagittal aspect through multi-planar reconstruction of 0.2 mm slices. The accuracy of this protocol has been previously published by Benninger *et al*.[10] The radiation exposure to each patient was 61 μSv.

The radiological assessment of the anatomical variants was done by analyzing the coronal sections of the scans. The CBCT scans were evaluated by a single examiner (R. S) and for interpretation of the sinus variants, assistance was provided by an experienced otolaryngologist. For calibration and assessment of intra-observer reliability, the patency of the OMC in the CBCT scans of 15 patients was randomly selected and measured by the investigator on three different days, resulting in a mean difference of 0.021 ± 0.02 mm and an intra-observer agreement of 0.97 was noted.

The variants observed were deviated nasal septum [Figure 1], uncinate process [Figure 2], agger nasi [Figure 3], Haller cells [Figure 4], middle turbinate variants [Figures 5 and 6], enlarged bulla [Figure 7], accessory ostium [Figure 8], and maxillary sinus abnormalities [Figure 9]. Ostium patency was evaluated in the coronal section of each sinus and classified as "patent" or "obstructed" The most common variants observed were then correlated.[11] Statistical analysis was performed using the IBM SPSS statistics (version 17, IBM Corp., USA, New York) software. Descriptively analysis was performed to understand the frequency distribution of the anatomic variants. The association between each variable and the patency of the OMC was then analyzed using Pearson's Chi-squared test. A significance value of $P < 0.05$ was considered as statistically significant.

RESULTS

The 71 scans studied showed an obliterated OMC in 52 patients. The incidence of the various anatomical structures included deviated nasal septum 29.5%, uncinate process variants 23.9%, agger nasi 7.04%, Haller cells 22.5%, middle turbinate variants 61.9%, enlarged bulla 63.4%, accessory ostium 12.6%, and sinus cavity abnormalities 35.2% [Table 1 and Figure 10]. Among all 71 scans observed, the overall prevalence of obliterated OMC was 73.2% due to the presence of one or more anatomic variants. The possibility of an obliterated OMC due to the presence of the four most common variants was the deviated nasal septum (76.2%), middle turbinate (86.4%), enlarged bulla (77.8%), and sinus cavity variants (80.0%). These variants were evaluated closely and co-related [Figure 8]. The results showed that middle turbinate variants in association with the other three

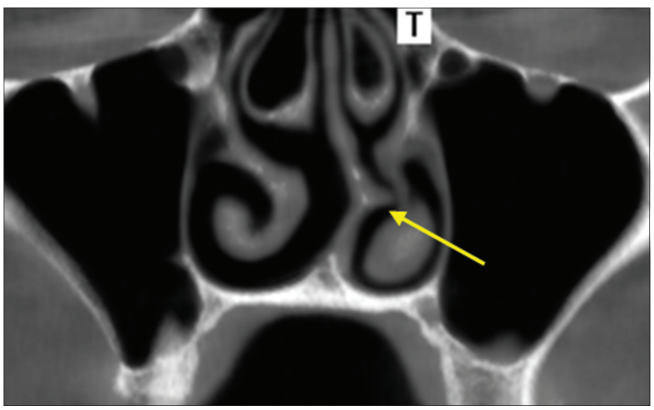

Figure 1: Deviated nasal septum and spur seen as an anatomical variant in the coronal section of the scan

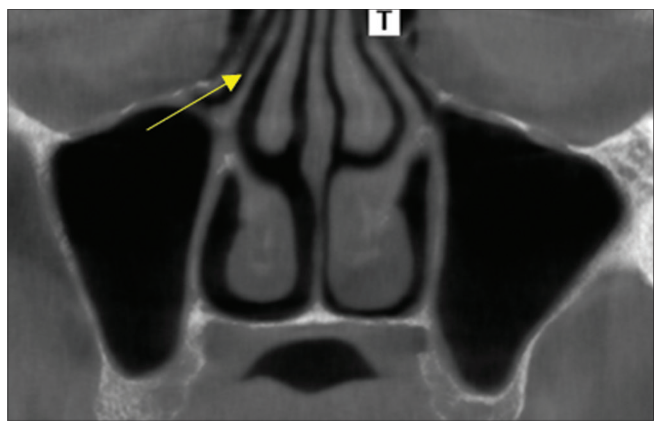

Figure 2: Centralized uncinate process seen as an anatomical variant in the coronal section of the scan

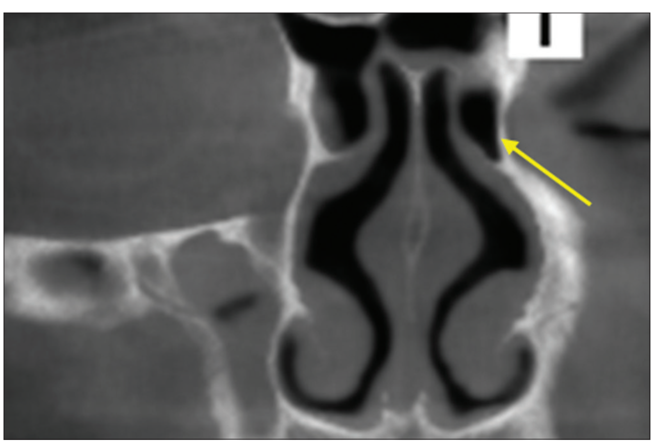

Figure 3: Agger Nasi seen as an anatomical variant in the coronal section of the scan

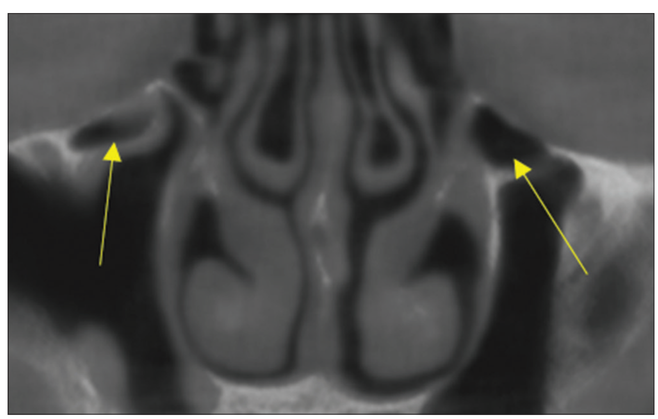

Figure 4: Haller cells seen as an anatomical variant in the coronal section of the scan

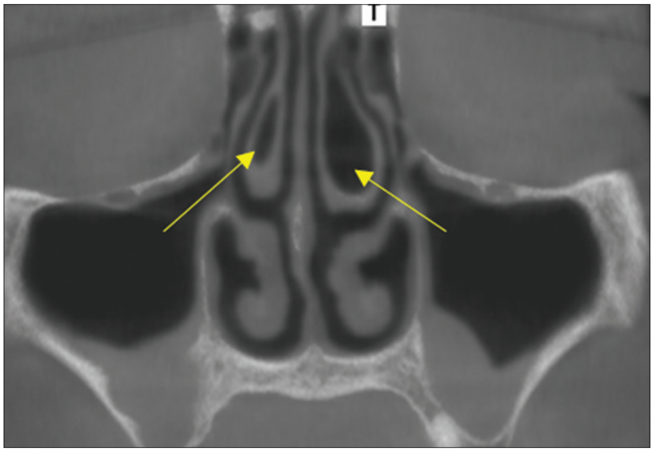

Figure 5: Concha bullosa seen as an anatomical variant in the coronal section of the scan

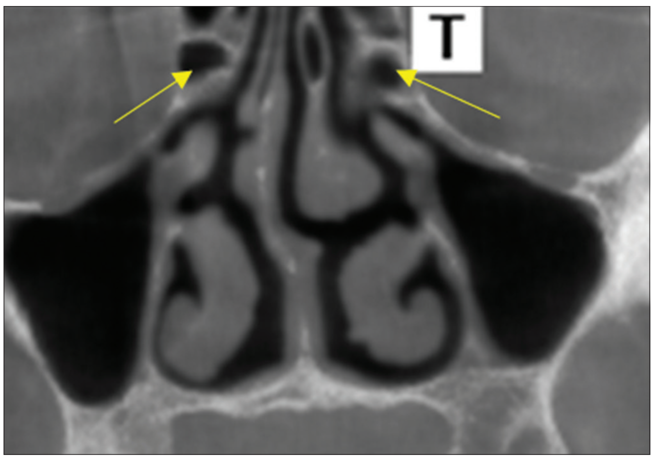

Figure 7: Enlarged bulla seen as an anatomical variant in the coronal section of the scan

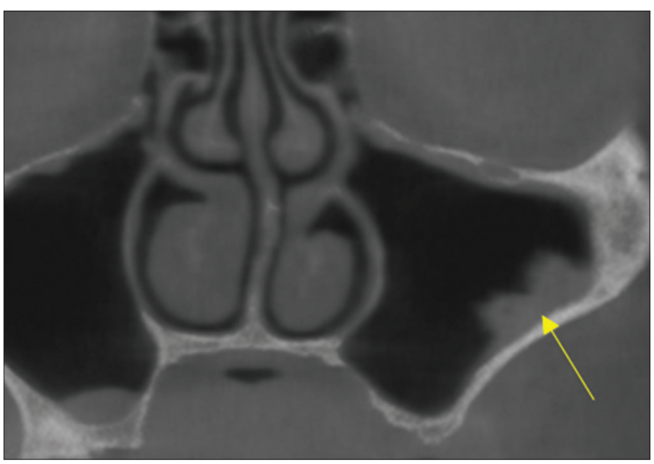

Figure 9: Polyp formation seen as an anatomical variant in the coronal section of the scan

variants, namely the deviated nasal septum, sinus cavity variants, and enlarged bulla, caused an obliterated OMC up to 81.3%, 86.7%, and 86.7% patients, respectively [Table 2 and Figure 11]. Chi-square test was performed to

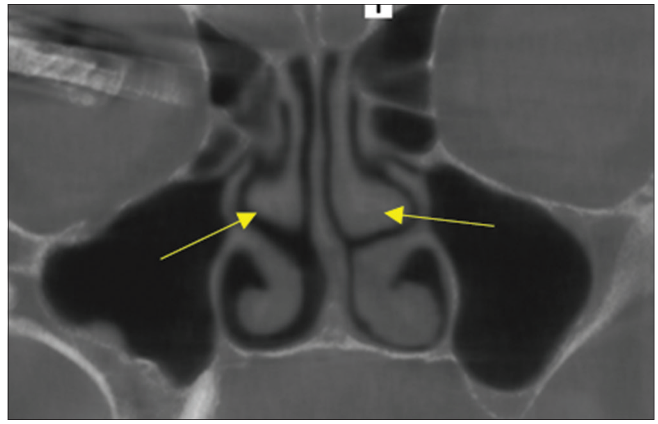

Figure 6: Paradoxical middle turbinate seen as an anatomical variant in the coronal section of the scan

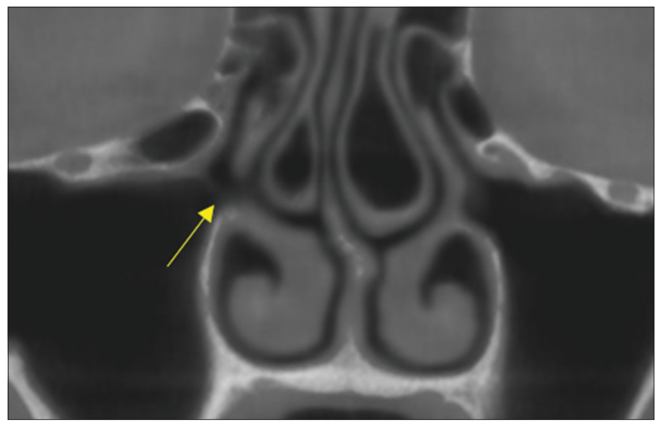

Figure 8: Accessory ostium seen as an anatomical variant in the coronal section of the scan

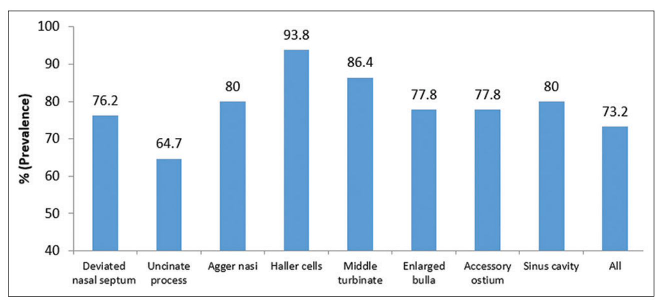

Figure 10: Prevalence rate of obliterated osteomeatal complex due to the anatomic variants seen

analyze the association between the anatomical variants and the patency of the OMC. A statistically significant association was observed for Haller cells ($P = 0.35$) and middle turbinate variants ($P < 0.001$) and the obliteration of the ostium [Table 3]. The association between other variants and patency of the OMC was statistically nonsignificant ($P > 0.05$). Similarly, the effect of gender on the patency of the osteometal complex was analyzed, a statistically nonsignificant difference was noted between the gender and patency of the OMC ($P = 0.260$).

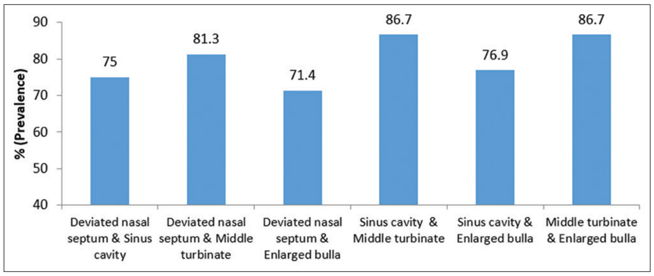

Figure 11: Prevalence of obliterated osteomeatal complex due to a combination of anatomic variants seen

Table 1: The prevalence of the anatomical variations and incidence of obliteration of the osteomeatal complex

Variations	Incidence, *n* (%)	Patent OMC, *n* (%)	Obliterated OMC, *n* (%)
Deviated nasal septum	21 (29.5)	5 (23.8)	16 (76.2)
Uncinate process	17 (23.9)	6 (35.3)	11 (64.7)
Agger nasi	5 (7.04)	1 (20.0)	4 (80.0)
Haller cells	16 (22.5)	1 (6.2)	15 (93.8)
Middle turbinate	44 (61.9)	6 (13.6)	38 (86.4)
Enlarged bulla	45 (63.4)	10 (22.2)	35 (77.8)
Accessory ostium	9 (12.6)	2 (22.2)	7 (77.8)
Sinus cavity variants	25 (35.2)	5 (20.0)	20 (80.0)
Total	71	19 (26.8)	52 (73.2)

n: Number of patients, OMC: Osteomeatal complex

Table 2: The incidence of obliteration of the osteomeatal complex when two variants co-existed

	Sinus cavity variants, *n* (%)	Middle turbinate variants, *n* (%)	Enlarged bulla, *n* (%)
Deviated nasal septum	8 (75.0)	16 (81.3)	14 (71.4)
Sinus cavity variants	-	15 (86.7)	13 (76.9)
Middle turbinate variants	-	-	30 (86.7)

Table 3: Chi-square test depicting association between anatomical variants and status of the osteomeatal complex

Variable	df	Value	*P*
Gender	1	1.268	0.260#
Deviated nasal septum	1	1.33	0.716#
Uncinate process	1	0.83	0.362#
Agger Nasi	1	0.12	0.723#
Haller cells	1	4.43	0.35*
Middle turbinate	1	10.16	0.001**
Enlarged bulla	1	1.29	0.256#
Accessory Ostium	1	0.10	0.742#
Sinus cavity (sinusitis, polyp, mucosal thickening)	1	0.90	0.343#

**Statistically highly significant ($P<0.001$),*Statistically significant ($P<0.05$), #statistically nonsignificant

DISCUSSION

The prerequisites for a successful sinus augmentation procedure include an efficient ciliary movement, a normal sinusal mucosa, and a patent sinus ostium.[6] The presence of anatomic variants can cause an obliterated OMC.[12] The incidence of anatomic variants of the OMC is quite high.[13-15] Earwaker reported 93% of cases presenting with one or more than one variant, while only 41% were considered "endoscopically normal."[16] Preoperative detection of such variations can help in avoiding postsurgical complications.[17]

In the present study, the most common anatomic variants seen were the variants in the middle turbinate (paradoxical middle turbinate/concha bullosa) followed by variants seen in the sinus cavity (sinusitis/polyps/mucosal thickening), enlarged bulla and a deviated nasal septum.

The prevalence of the obliterated OMC in the present study was 73.2% amongst all 71 cases observed. This result was in agreement with the work of Fadda *et al.*, who reported a prevalence rate of obliterated OMC of 75.7% due to various anatomic variants.[15]

Middle turbinate variants seen were the concha bullosa and paradoxical bent. The association between the presence of middle turbinate variants and the obliteration of the OMC was statistically highly significant [Table 3]. Middle turbinate variants seen were the concha bullosa and paradoxical bent. The present study reports the incidence of middle turbinate variants in 61.9% of cases. In the past, studies have reported a frequency ranging from 18% to 73%.[8,18,19] This wide variation observed was due to the criteria of pneumatization adopted.[8]

In this study, the incidence of an obliterated OMC was seen to be 86.4% from the 44 cases that presented with this anatomic variant. Concha bullosa is a common anatomic variant and does not require surgery. Its presence narrows down the OMC and can lead to subsequent sinus disease.[20] Earwaker reported that middle turbinate variants were associated with septal deviation. 79% of cases had deviated nasal septum (single curvature) and presented with an abnormally large middle turbinate.[14] Jorissen *et al.* in their study reported the commonly associated variants with sinus pathology as septal deviation, true concha bullosa, and accessory opening. They concluded that knowledge of the anatomic variants is most important to prevent any surgical complication.[13]

In the present study, the incidence of the deviated nasal septum was 29.5%. This is in accordance with a study conducted by Riello and Boasquevisque which presented an incidence rate of 28.5%.[21]

Amongst the 21 cases presenting a deviated nasal septum, 76.2% of cases had an obliterated OMC, whereas the remaining cases showed a patent OMC. The side to which the deviation takes place undergoes compensatory structural changes, thereby causing a loss of patency of the ostium and a corresponding disease in OMC.[18]

This study reported an incidence of 35.2% of sinus cavity abnormalities. The frequency of sinus cavity abnormalities reported in the literature has been diverse, ranging from 24.4%-85.7%.[21] The results of this study were within these reported ranges. The 25 patients presenting with sinus cavity variants showed a prevalence of obstructed OMC in 80% of them. A high incidence of this variant is observed in patients with asymptomatic chronic sinus disease, mild undiagnosed chronic sinusitis, or normal variations in the sinus mucosa. A detailed medical history and endoscopic examination are required to understand the background of mucosal abnormalities of the maxillary sinus.[22,23]

The incidence of an enlarged bulla in the present study was 63.4%. Previous studies have reported a varied incidence of the same as 8%, 26.75%, and 32.8%).[15,16,24] However, the exact incidence of an enlarged ethmoid bulla is not known.[25] The prevalence of obliterated OMC assessed was 77.8% out of the 45 patients presenting with an enlarged bulla. The presence of Haller cells was statistically significantly associated with the obliteration of the OMC [Table 3]. This was also reported in a study conducted by Zinreich *et al*.[24] reported that the presence of Haller cells and lateral deviation of the uncinate process could contribute to the narrowing of the infundibulum, thus leading to compromise in the patency of the OMC. The incidence of Haller cells was noted to be 22.5% in this study. Out of the 16 cases identified with Haller cells, 93.8% demonstrated the obliteration of OMC.

This is in agreement with a recent clinical study, Lee *et al*. noted that the presence of Haller cells is commonly observed between the maxillary sinus and orbital floor. The presence of Haller cells constricts the ostium and is known to be a common etiologic factor for recurrent sinusitis.[26]

It can be seen from Table 1 and Figure 10 that anatomic variants do not occur in isolation but are frequently seen in conjunction with other variants. In the present study, the most commonly observed anatomic variants were the deviated nasal septum, variants in the middle turbinate (paradoxical middle turbinate/concha bullosa), variants seen in the sinus cavity (sinusitis/polyps/mucosal thickening) and enlarged bulla. These were correlated, and the prevalence of an obliterated OMC was determined [Table 2 and Figure 11]. When the four most common variants occur as co-variants, the incidence of OMC obliteration was highest (86.7%) when middle turbinate variants exist with enlarged bulla.

Tao *et al*. studied the anatomic variants in the OMC between both the sides of a deviated nasal septum and concluded that deviation of the nasal septum causes compensatory structural changes in the middle turbinate which included concha bullosa on the contralateral side and a prominent enlarged bulla. The side towards which deviation occurs showed a higher incidence of the paradoxical middle turbinate.[27]

The patients with evidence of sinusitis had a higher degree of septal deviation.[28] The increasing septal deviation causes obstruction of the OMC in the direction of septal angulation, thereby leading to an increased incidence of sinus disease.[29]

A recent study in the Indian population noted 32% prevalence of septae. They stated that the presence of septa is one of the commonly seen anomalies in the maxillary sinus and should be considered before sinus floor augmentation. The presence of septa increases the chances of complications like tearing of the Schneiderian membrane during sinus floor augmentation.[30]

Although these variations compromise normal drainage pathways and lead to a significant obstruction at the level of frontal recess and the OMC, they do not necessarily represent a diseased state. Careful evaluation of the sinus and the OMC must be done before surgical intervention to identify the potential risk of exacerbating compromised drainage leading to obliteration of the OMC.

The obstruction of the OMC causes a vicious cycle of events with increased disease burden overall. The absence of drainage of mucus from the middle meatus in the posterior nasopharynx may lead to an infection of the sinus graft.[31] Thus predisposing the patient to significantly greater postoperative problems, thereby requiring more rigorous postoperative monitoring and probably a prolonged antibiotic and supportive therapy.

A recent retrospective study highlighted the importance of the location of the maxillary sinus ostium. They noted that distance between the sinus floor and maxillary ostium is approximately 28.5 mm, which may be a limiting factor for sinus augmentation procedures. In such cases overfilling the sinus with biomaterial may lead to sinusitis and hypoplasia.[32]

The authors of the present study suggest that careful radiographic examination should be performed for patients undergoing sinus augmentation procedures. In the presence of anatomic variations of the OMC, the presence of an obliterated ostium can be predicted, should be anticipated, and if needed, be confirmed by endoscopic examination. This would help in organizing better intra and postoperative care, which would prepare the surgeon and patient for a longer postsurgical inflammatory period and have an effect on the long term success of the sinus graft.

The limitations of the study are its relatively small size and retrospective study design, the evaluation of any variations existing in the left and right side of the sinus could also be done. Further studies should be performed with larger sample size, and an endoscopy could be performed for confirmation of radiological findings. The effect of patency of ostium on the success of sinus augmentation procedures should also be evaluated postsurgery.

CONCLUSIONS

In this study, the incidence of an obliterated OMC due to the presence of anatomic variants was 73.2%. The results of this study suggest that a thorough pretreatment evaluation (radiographic and if needed endoscopic) of the status of the OMC can help in predicting and avoiding postsurgical complications, initiating more vigorous postoperative care and allow better consolidation of the graft with a low morbidity rate.

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Conflicts of interest
There are no conflicts of interest.

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