sciendo

10.2478/AMB-2022-0027

ORIGINAL ARTICLE

ANATOMICAL VARIATIONS OF THE MAXILLARY SINUS – A CONE BEAM COMPUTED TOMOGRAPHY STUDY

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Abstract. Objectives: *The knowledge of the normal morphology of the maxillary sinuses and their variations is important for maxillofacial radiologists to achieve a better evaluation and delineation of pathologies and for pre-implant evaluation of the maxilla.* ***The aim*** *of our study was to evaluate anatomical variations of maxillary sinuses using Cone Beam Computed Tomography (CBCT).* ***Materials and methods:*** *150 CBCT images where bilateral maxillary sinuses were scanned were included in the study following the inclusion and exclusion criteria. 75 CBCT scans each of males and females were studied using the Planmeca Romexis software (Version 4.6.2). Multiplanar images were searched for the presence of anatomical variations such as septae, haller cells and ethmomaxillary sinus. The data were subjected to Chi square test using SPSS software to compare and relate gender and site based differences in the occurrence of the anatomical variations.* ***Results:*** *Sinus septa was the predominant variation in both males and females with significantly higher prevalence in females and on the right side. An ethmomaxillary sinus was seen significantly more often in males, while Haller cells did not show any gender based differences in their occurrence. Ethmomaxillary sinus and Haller cells showed no difference in occurrence on the right and left side.* ***Conclusions:*** *Anatomic variations of the maxillary sinuses are a common finding. It necessary for the clinicians to be familiar with these variations to avoid clinical complications especially in cases of implant placements.*

Key words: *anatomic variation, maxillary sinus, prevalence, radiology, sinusitis*

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Received: *8 February 2022 –* ***Accepted:*** *3 March 2022*

INTRODUCTION

The maxillary sinus is the major paranasal sinus and is of principal interest for otolaryngologists, oral maxillofacial surgeons and maxillofacial radiologists. Nathaniel Highmore, an English anatomist described the maxillary sinuses as early as 1651. The maxillary sinus is a significant structure that is present within the maxilla and is closely associated with the alveolar process [1]. The structure of the maxillary sinus is complex and may present variations in their anatomy. These variations can lead to clinical presentations for which the patients may seek aid in specialties like ophthalmology or dentistry, rather than otorhinolaryngology [2].

Three-dimensional imaging modalities such as Computed tomography (CT) and Cone beam computed tomography (CBCT) are the preferred modalities for imaging of the maxillary sinus and diagnosing sinus pathologies [3]. CBCT has emerged as a widely used imaging technique for the dental and maxillofacial region including the maxillary sinuses. CBCT can help in the assessment of the osseous as well as the mucosal component of the maxillary sinuses [4]. Anatomical differences in the maxillary sinuses are recognised to have various clinical significance, but their characteristic presentation and occurrence vary greatly. Therefore this study aimed to evaluate the anatomical variations of maxillary sinuses and their prevalence using CBCT scans.

MATERIALS AND METHODS

This study was performed after obtaining approval from the institutional ethical and research committee (Certificate no: ETHICS/ABSMIDS/187/2022). The CBCT data of subjects referred to the Department of Maxillofacial Radiology, A. B. Shetty Memorial Institute of Dental Sciences, Mangalore from the period of January 2019 to December 2021 were included in the study. Inclusion criteria: Patients aged between 10 to 40 years with bilateral maxillary sinuses seen without any artefacts. CBCT images with surgical reconstructions, fractures, clefts, cysts, tumors of the odontogenic and sino nasal mucosa and those with artefacts were not included in this study. A total of 150 scans (75 males and 75 females) that fulfilled the inclusion criteria were randomly selected. All the CBCT scans were obtained with the Planmeca Promax 3D CBCT scanner (Helsinki, Finland) using a standard protocol with exposure parameters of 80-90 kV, 8-10 mA and voxel size ranging from 200-400 µm. The CBCT volumes were assessed by two independent maxillofacial radiologists. The scans were studied using the Planmeca Romexis software (Version 4.6.2) in multiplanar reconstructions to detect various anatomical variations such as Sinus septa, Haller cells and Ethmomaxillary sinus. The data were analysed statistically using the SPSS software version 26. The Chi square test was used to compare and correlate the gender and site based differences in the anatomical variations.

RESULTS

Out of the 150 CBCT scans, 75 were of males and 75 – of females. The mean age of males was 36 ± 5.2 years and of the females was 29 ± 7.6 years. Anatomical variations were detected in 30 males and 38 females. Most of the anatomical variations occurred on the right side and were more prevalent in females. Sinus septa was the predominant variation in both males and females, with significantly increased rate in females (p-value = 0.022). Ethmomaxillary sinus was seen significantly more often in males (p-value = 0.016). While Haller cells showed no significant difference in their occurrence between males and females (p-value > 0.05) (Table 1, Figure 1). Most of the septae were found on the right side (p-value = 0.007). But, the ethmomaxillary sinus and Haller cells showed no difference in their occurrence on the right and left side (p-value > 0.05) (Table 2).

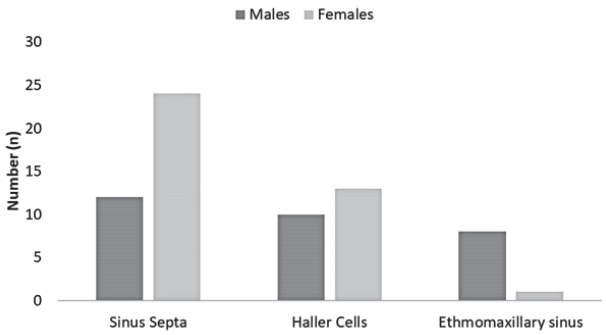


Fig. 1. Distribution of various anatomical variations of maxillary sinuses

Table 1. Distribution of anatomical variants based on gender

Anatomical Variation	Males	Females	p-value
Sinus Septa	12	24	**0.022**
Haller Cells	10	13	0.497
Ethmomaxillary sinus	8	1	**0.016**

Table 2. Distribution of anatomical variants based on the side of occurrence

Anatomical Variation	Right side	Left side	p-value
Sinus Septa	28	12	**0.007**
Haller Cells	16	9	0.144
Ethmomaxillary sinus	7	4	0.357

DISCUSSION

Cone Beam Computed Tomography (CBCT) is a comprehensive diagnostic tool that can reliably capture and provide a three-dimensional visualisation of the anatomy and pathology of the maxillofacial region since its introduction in the field of dental care in the year 1998 [5]. The American Academy of Oral and Maxillofacial Radiology recommends

the use of CBCT as an alternative to conventional CT for three dimensional imaging of maxillofacial structures [6, 7]. A precise knowledge of the different anatomical variations and pathologies of the maxillary sinus is crucial for clinical practice in dentistry, maxillofacial surgery and otolaryngology. In dentistry, evaluation of maxillary sinuses requires special attention especially during dental implant surgeries [8]. Due to the close proximity of the maxillary sinus to the posterior teeth, a three-dimensional preoperative assessment of the maxillary sinus is also considered to be fundamental in planning pre-prosthetic surgeries [5, 9].

Sinus lift procedure is a common technique prior to implant placements in the atrophic maxilla. In such cases, adequate radiological evaluation of the maxillary sinus is necessary to reduce complications due to the existence of a major morphologic variability in the maxillary sinuses [8]. Van Den Bergh et al. emphasized that the demonstration of the maxillary sinus septa in 3D images aids the surgeons to follow appropriate surgical strategies to avoid complications during sinus lift procedures [9,10]. Maxillary sinus septae are barriers of cortical bone within the sinus. (Figure 2a) The renowned anatomist “Arthur S Underwood” was the first to describe the maxillary sinus septa, which is also known as Underwood’s septa [5]. These Septae are known to be derived from the outpouching of the infundibulum without the resorption of adjacent walls [11]. Sinus septae are formed at separate stages of tooth eruption which explains the high variability of this structure [12]. Occasionally, the maxillary sinus can be divided into numerous compartments due to the presence of septations [9].

In our study of 150 CBCT scans, septae were the most commonly observed morphological variant with a prevalence rate of 24.0%. These findings were in accordance with the studies reported by Kim et al. and Koymen et al. [11, 13]. However, literature sources show various prevalence rates of septae ranging from 9.5% to 65.0% depending on the population studied and the diagnostic modality used [14]. We found most of the septa on the right side, which is consistent with previous studies [13-15].

Women showed a higher predominance for sinus septa. But, studies by Kim et al. and Koymen et al. have reported a male predominance. It was postulated that increased occurrence of septa in males could be explained on the basis of the mean maximum bite force of males which is usually higher than that of the females [11, 13, 16]. But the variability in gender predilection observed in our study could be influenced by factors including ethnicity and presence of edentulism.

There are various classifications of the sinus septae available in the literature, but the classification proposed by Sigaroudi et al. in 2017 which is a modification of the Al-Faraje classification (2011) was followed in our study for classifying the septae owing to its clinical relevance [12]. In the present study, Class-III type had the highest prevalence (41.7%) which is in accordance with the previous study by Alhumaidan et al. [17]. A majority of septae in this region were found in the molar region and might lead to irregular pneumatization of the sinus in edentulous cases, harbouring a moderate risk of sinus perforation during implant placements [17, 18]. The second most common pattern of sinus septae was Class I type (30.5%) followed by Class V type (22.2%) that were short septations with very low probability of interference with the sinus lift procedures and lateral window approaches. The least observed pattern was Class VII-Division I (5.5%) which is reported to possess a moderate to high risk of sinus perforation resulting in acute or chronic sinusitis and can lead to the resorption of adjacent bone [5] (Figure 3). CBCT evaluation of the posterior maxillary implant sites can aid the implantologist to understand the morphology of the maxillary sinus and to perform necessary modifications before placing an implant [11, 16].

The second most significant anatomic variation that was observed in our study was the presence of Haller cells. (Figure 2b) Haller (infra-orbital ethmoid) cells are air-filled cavities located infero-laterally to the ethmoidal bulla. In the presence of any infection, these cells expand along the medial portion of the orbital floor, superior to the ethmoidal infundibulum, thereby causing constriction of the osteomeatal complex [19, 20]. Prevalence rates ranging from 5.5% to 45.9% have been reported in various studies [19]. We observed Haller cells in 15.3% of the samples studied [21, 22]. Our study followed the strict criteria formulated by Mathew et al. for defining the Haller cells. According to Mathew et al., air cells of any size that are found along the medial aspect of the orbital floor and/or the lamina papyracea if seen inferior to the bulla ethmoidalis are considered as Haller cells. These cells are distinguished from the infraorbital recess of the maxillary sinus by their link with the ethmoid capsule [21]. We observed no significant difference in the prevalence of Haller cells between genders, but a higher prevalence was seen on the right side. Previous studies by Pekiner et al. and Raina et al. also revealed an increased frequency of Haller cells on the right side [22, 23]. The presence of infraorbital ethmoidal cells can predispose to sinus pathologies by accelerating the inflammatory process, thus complicating sinus surgery [20, 22]. As

a result of infection, mucosal swelling can readily restrict secretion transportation, thereby contributing to the vicious cycle that can lead to rhino-sinusitis [19]. According to published literature, the presence of inflamed Haller cells can serve as a potential contributing factor for the development of unilateral orbital cellulitis [21]. Hence, Haller cells are considered to be a significant variation that could have an impact on the health of the sinus.

The least commonly observed anatomical variant found in our study samples was ethmomaxillary sinus (Figure 2c). The most posterior ethmoidal cells expand and enter the maxillary sinus draining into the superior nasal meatus resulting in the formation of ethmomaxillary sinus (EMS) [24]. Previous studies have reported that this anatomical variant of the paranasal sinus can limit the mucociliary clearance, thus predisposing the patients to chronic rhino-sinusitis [25]. We found EMS to be the least common variant with a prevalence of 6.0% which is in accordance with the studies done by Dasar et al. and Liu et al. [26, 27]. In our study, EMS was found to be associated with male gender, but there was no significant difference in the side of occurrence (left/right). Our results were compatible with the findings of Ozcan et al. and Liu et al. [24, 26]. Knowledge of the radiographic imaging and appearance of EMS is essential since residual lesions may occur if the surgeon is unfamiliar with the presence of EMS and performs merely the Middle Meatus Antrostomy (MMA). The presence of a large EMS can also diminish the medial wall of the maxillary sinus which corresponds to the middle nasal meatus, thus further complicating MMA [24]. Further, the degree of pneumatisation of the EMS may be associated with rhino-sinusitis [26, 27]. The greater the degree of pneumatisation of the EMS, the greater the compression of the ipsilateral maxillary sinus, which can lead to obstruction causing chronic rhino-sinusitis [25]. Liu et al. showed that chronic rhino-sinusitis was prevalent in 60.9% of the individuals with EMS [26]. Thus, the sinu-nasal region which hosts a number of anatomical variations that are known to be associated with the sinu-nasal disease demands multiplanar radiologic analysis to improve the efficient surgical planning. Application of CBCT in imaging protocols of the sinu-nasal region has various advantages such as lower radiation doses with adequate spatial resolution in the context of evaluation of bone structures and associated diseases.

CONCLUSION

Anatomic variations are common in the maxillary sinuses, therefore it necessary for the clinicians to be familiar with these variations to avoid clinical complications. Our study is an attempt to display the prevalence and common anatomical variants to be expected. However, our study is influenced by certain inherent limitations such as small sample size, lack of a detailed assessment of the osteo-metal complex. Further large prospective studies with complete assessment of the sinu-nasal architecture along with the associated pathologies should be performed to provide a deeper insight.



Fig. 2a. Sagittal CBCT image showing septa arising from the wall of sinus. **2b.** Coronal CT image showing Haller cell on the left maxillary sinus. **2c.** Coronal CT image showing ethmomaxillary sinus on the left maxillary sinus

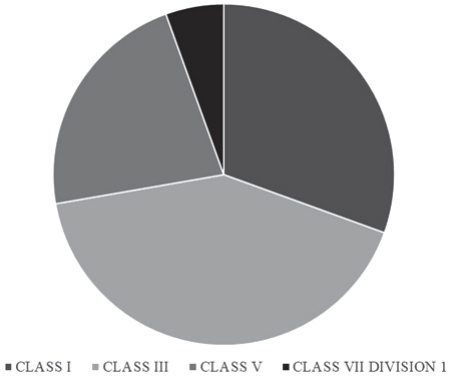


Fig. 3. Prevalence of various types of sinus septa

Acknowledgements: *None*

Funding sources: *None*

Disclosure Summary: *The authors have nothing to disclose*

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