ORIGINAL ARTICLE
ISSN 2645-4351
https://doi.org/10.22037/jds.v43i1.46792

Exploring Maxillary Sinus Ostium Characteristics and Insights for Pathology Prediction and Anatomical Variations: A Cone Beam Computed Tomography (CBCT) Analysis

Solmaz Valizadeh[a], Mitra Ghazizadeh Ahsaie[a], Farnaz Fotuhi Firoozabad[a], Seyed Sasan Aryanezhad[b], S. Marjan Arianezhad[c],*

[a]Department of Oral and Maxillofacial Radiology, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[b]Department of Oral & Maxillofacial Radiology, school of Dentistry, Islamic Azad university of Isfahan (Khorasgan), Isfahan, Iran.
[c]Department of Oral and Maxillofacial Radiology and Research Committee, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
Correspondence to: S. Marjan Arianezhad, Email: marjan.arianezhad@gmail.com

Submitted: 20 November2024
Revised: 30 November 2024
Accepted: 7 December2024
Published: Winter 2025

How to cite:
Valizadeh S, Ghazizadeh Ahsaie M, Fotuhi Firoozabad F, Aryanezhad SS, Arianezhad SM. Exploring Maxillary Sinus Ostium Characteristics and Insights for Pathology Prediction and Anatomical Variations: A Cone Beam Computed Tomography (CBCT) Analysis. J Dent Sch 2025;43(1):1-9.

Abstract

Objectives: Understanding the anatomy of the maxillary sinus is essential for ensuring a successful surgical procedure. This study utilized CBCT to evaluate the relationship between maxillary sinus ostium characteristics, adjacent anatomical structures, and pathologies. **Methods:** A retrospective evaluation was conducted on CBCT images of 400 maxillary sinuses. Measurements included the height and dimensions of the ostium, as well as the length of the infundibulum. The study investigated maxillary sinus pathologies, anatomical variations, and the associations between the characteristics of the maxillary sinus ostium and adjacent anatomical structures. Statistical analyses were performed using Pearson's Chi-Square test, simple logistic regression, multiple logistic regression, and multiple linear regression models at p<0.05. **Results:** The mean ±SD for ostium height, size of the ostium entry, and infundibulum length were 31.08±4.99mm, 1.72±2.03 mm, and 7.81±1.73 mm, respectively. An increase in Haller cell and infundibulum length raised the risk of a mucosal membrane in the ostium area. The Ostium height was significantly higher in males (P<0.05). Mucosal thickening (MT) was considerably higher in patients with positive maxillary sinus septum (P<0.005). Infundibulum length, nasal septum deviation, and Haller cell significantly affected sinus opacity rate (P<0.001). In cases where the deviation was towards the sinuses, maxillary sinus pathologies occurred more frequently. Age and gender significantly affected MT, the mucous membrane in the ostium, and at least one sinus pathology (P<0.05). **Conclusion:** Maxillary sinus pathologies can be evaluated by increasing the infundibulum length and reducing the ostium size. CBCT evaluation is crucial for successful surgery and preventing complications. Accurate assessment of sinuses and nasal passages in the elderly is recommended.

Keywords: Sinus Ostia; Membranes Mucous; Maxillary Sinus; Cone-Beam Computed Tomography; Pathology

Introduction

The maxillary sinus, the largest of the paranasal sinuses, serves critical functions such as enhancing vocal resonance, reducing cranial weight, protecting the skull base from trauma, and conditioning inhaled air by warming and humidifying it.[1] Mucosal drainage in healthy sinuses occurs through the osteomeatal complex (OMC), where mucus is directed toward the ostium via the infundibulum, a narrow passage connecting the sinus to the nasal cavity.[2]
A comprehensive understanding of maxillary sinus anatomy and its variations is essential for planning surgeries such as sinus floor elevation (SFE) or functional endoscopic sinus surgery (FESS). Such knowledge can minimize the risk of intraoperative complications.[3,4]
Rehabilitation of patients with posterior maxillary implants can be complicated by maxillary sinus pneumatization and ridge atrophy.[8,9] One of the most common complications during SFE is the perforation of the Schneiderian membrane, which can lead to sinusitis or other pathologies, adversely affecting the patient's quality of life.[10–12]
Cone beam computed tomography (CBCT) is a widely used imaging modality for detailed three-dimensional evaluation of the jaws and sinuses. It provides high-resolution imaging with reduced radiation exposure compared to traditional CT, making it an excellent option for sinus evaluations.[6–10]
Nasal septal deviation can cause congestion of the middle concha, obstruct the middle meatus, and impair mucus drainage from the sinuses.[11] Other anatomical variations, such as concha bullosa, Haller cells, or deviated septa, may block the sinus ostium and predispose patients to sinusitis.[12] Infected Haller cells, a normal anatomical variation, can lead to chronic sinusitis.[13] Similarly, the Schneiderian membrane may thicken substantially in response to infection, with smoking and gender being identified as contributing factors.[14]

The influence of nasal septal deviation and concha bullosa on maxillary sinusitis remains unclear, and the role of infundibulum length in sinus drainage is also debated.[15] Anatomical variations in the maxillary sinus significantly impact sinus pathologies and surgical outcomes.[12,16] However, there is limited consensus on the relationship between sinus ostium characteristics, anatomical variations in adjacent structures, and sinus pathologies, particularly when evaluated using CBCT. Moreover, research on the effects of infundibulum shape and ostium features on maxillary sinus health is scarce. This study investigated these relationships by analyzing CBCT findings, focusing on maxillary sinus ostium characteristics, adjacent structures, and inflammatory pathologies.

Methods

This retrospective evaluation was conducted on CBCT images of 400 maxillary sinuses in 200 patients.

In this retrospective cross-sectional study, CBCT images were sourced from the archives of two primary dental radiology centers in Tehran. The sample comprised male and female participants aged 18 to 76 years. The study protocol received approval from the institutional review board of Shahid Beheshti University of Medical Sciences (Approval Code: IR.SBMU.DRC.REC.1400.137) and adhered to the principles outlined in the Declaration of Helsinki, its subsequent revisions, and the STROBE guidelines. Although the calculated sample size was 194 scans, it was increased to 200 to enhance accuracy. Sociodemographic data, including age and gender, were recorded at the time of CBCT imaging.

Evaluation of CBCT Scans:

CBCT images of the maxillary sinus were randomly selected from September 2019 to September 2023. Scanning was performed using the NewTom VGI CBCT scanner (Quantitative Radiology, Verona, Italy) for routine dental treatments. Importantly, no additional radiation was administered to participants beyond standard protocols. Institutional policies required patient consent for inclusion in research, with full disclosure of potential benefits and risks.

Inclusion criteria:

1. Participants aged 18 years or older to ensure the complete development of maxillary sinuses.
2. CBCT images with an adequate resolution and diagnostic quality.
3. The field of view of the CBCT images had to clearly include complete bilateral maxillary sinuses.[17]

Exclusion Criteria:[17]

1. CBCT scans showing maxillofacial trauma, history of orthognathic surgery, or congenital anomalies.
2. Presence of pathologies such as cysts, tumors, impacted teeth, dental implants, or bone grafts.
3. Patients on medications affecting bone metabolism (e.g., bisphosphonates) or with conditions like osteoporosis that could compromise bone quality and CBCT image clarity.
4. CBCT images with artifacts caused by beam hardening, noise, metal objects, or ring effects.

Measurements:

All measurements were conducted by a specialized oral and maxillofacial radiologist. Intra-observer reliability was confirmed via the intra-class correlation coefficient (ICC), with 20 CBCT scans re-evaluated one month apart. Image analysis was performed using on-demand 3D software (CyberMed, Version 1.0.10.6388). Axial, coronal, and sagittal two-dimensional multi-planar reconstructions were utilized to enhance diagnostic accuracy, with evaluators blinded to participant details.

The primary objective was to investigate the relationship between maxillary sinus ostium characteristics and sinus pathologies, alongside anatomical variations in adjacent structures. Measurements included ostium entry size, ostium height, infundibulum length, and the prevalence of anatomical variations (e.g., maxillary sinus septa, concha bullosa, septal deviation, and Haller cells) and sinus pathologies (e.g., mucosal thickening, antral pseudocysts, partial and total opacifications).

Ostium entry size: First, by scrolling through the coronal view, the section with the lowest position of the maxillary sinus floor and open and visible ostium was selected. The ostium entry size was calculated using a digital ruler by determining the distance between two input edges of the ostium (in millimeters). To enhance accuracy, measurements were taken in two adjacent slices with a one millimeter interval. This procedure was repeated three times for each sinus, and the average of the readings was calculated. The ostium entry size is shown in Figure 1a.

Height of the ostium: A line was drawn parallel to the tangent at the lowest point of the maxillary sinus using a digital software ruler on the same coronal CBCT section to measure distance. A perpendicular line was then drawn at the center of the ostium entry, and the distance was calculated by measuring the distance between two parallel lines, A (passing through the center of the ostium entry) and B (passing through the lowest point of the maxillary sinus). To enhance accuracy, measurements were taken in two adjacent slices with a one millimeter interval, repeated three times for each sinus, and the average of these readings was calculated. The height of the ostium is shown in Figure 1b.

Length of infundibulum: The distance between the ostium's center and the uncinate process's highest point was measured using coronal CBCT sections. This measurement was performed using the Digital Ruler software. To enhance accuracy, measurements were taken in two adjacent slices with a one millimeter interval, and each measurement was repeated three times for each sinus. The average of these readings was then calculated. Figure 1c displays the length of the infundibulum.

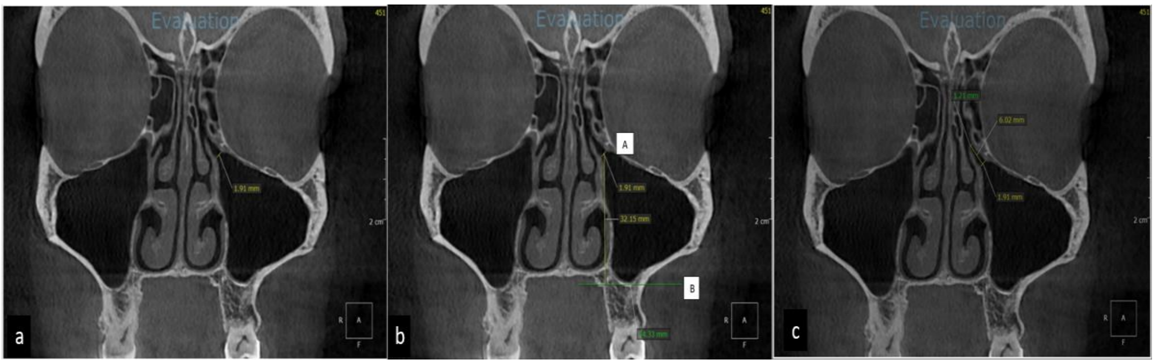

Figure 1: Coronal CBCT images of maxillary sinus and osteomeatal complex shows linear measurement of (a) Ostium entry size, (b) Height of ostium, (c) Length of infundibulum.

Nasal septum deviation (NSD): Deviation was defined by drawing a midline from the crista galli to the ANS-PNS plane. NSD was determined as a deviation greater than 4 mm from the midline, either to the right or left, according to Smith et al.[18]. The images with the highest deviations were measured by scrolling from posterior to anterior. In case of deviation (>4mm from the midline), the direction of deviation, whether right or left, was assessed. The direction of deviation was determined by the side of the convexity of the nasal septum.[11] Figure 2a displays the nasal septum deviation.

Concha bullosa (CB): In the coronal view, an air cavity in the middle turbinate on the left or right side, regardless of size, was classified as a concha bullosa. The status of concha bullosa, whether unilateral or bilateral, and its location, either on the left or right side, was noted. Figures 2b and 2c display the images of unilateral and bilateral concha bullosa, with arrows indicating their location.

Haller cell (HC): In the coronal view, Haller cell refers to the ethmoidal pneumatization of the superior aspect of the maxillary sinus and floor of the orbit. Its unilateral or bilateral position and location, either on the left or right side, were considered. Figures 2d and 2e display unilateral and bilateral Haller cells, with arrows indicating their location.

Maxillary sinus septa (MSS): The sinus septa is a thin bony wall protruding from the sinus walls. A sinus with more than one septum was considered multiple septa, and when extended from one wall to another wall, it was named complete septa. Septa presence on both sides was known as bilateral sinus septa with either sagittal, coronal, or axial orientation. We observed whether the septa were unilateral or bilateral and their positions on the left or right side. Figures 2f and 2g display the images of unilateral and bilateral maxillary sinus septa, respectively.

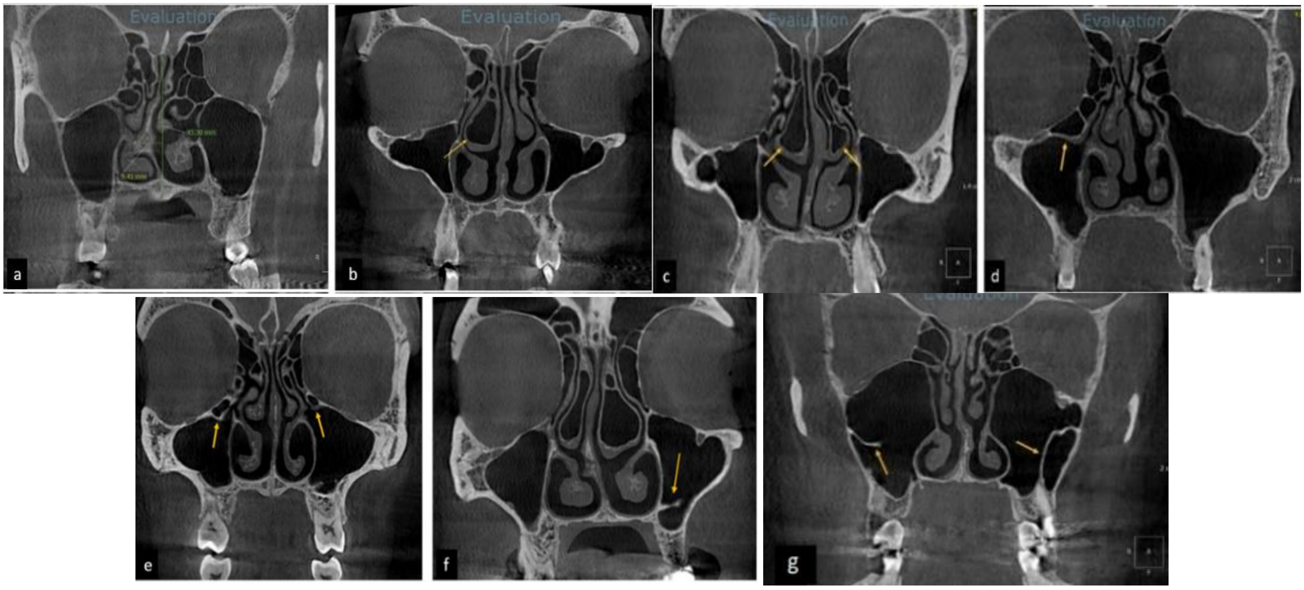

Figure 2: Coronal CBCT images of maxillary sinus and osteomeatal complex shows (a):Nasal septum deviation to the right, (b) Unilateral concha bullosa, (c) Bilateral concha bullosa, (d) Unilateral haller cell, (d) Bilateral haller cell,(e) Unilateral maxillary sinus septa, (f) Bilateral maxillary sinus septa

Sinus opacity: By scrolling through the coronal view, the section with the highest opacity and sinus mucosa was selected. To measure the opacity of the sinus, the area of mucosal thickening was measured from the sinus floor to the highest point related to the mucosa. The results were categorized and recorded as follows:

Normal: A mucosal thickening of less than 2mm in the maxillary sinus was considered within the normal range, as shown in Figure 3a.

Opacity level: In the maxillary sinuses with mucosal thickening, the distance between the sinus floor and the highest border of maxillary mucosa was measured using a software digital caliber and recorded as the opacity level of the maxillary sinus.

Mucous thickening (MT): A thickened mucosal membrane was identified by a linear appearance of 2-5 millimeters on any of the walls of the maxillary sinus, as illustrated in Fig 3b.

Antral pseudocyst (AP): An antral pseudocyst is a dome-shaped opacity with a distinct margin on any of the walls of the maxillary sinus, as illustrated in Figure 3c.

Partial opacity (PO): A mucosal thickening of more than 5 mm in any of the maxillary sinus walls was considered partial opacity, as shown in Figure 3d.

Total opacity (TO): Total opacity was considered the maxillary sinus's complete opacity, as shown in Figure 3e with an arrow.

The mucosal membrane in the ostium: In the section with a visible ostium, a distinct mucosal membrane with extension to the surrounding walls was defined as the mucosal membrane in the ostium, as illustrated in Figure 3f.

Blocked ostium: If the ostium was entirely blocked by the mucosal membrane and not visible in any sections, it was recorded as a blocked ostium. Figure 3g illustrates a blocked ostium in the maxillary sinus.

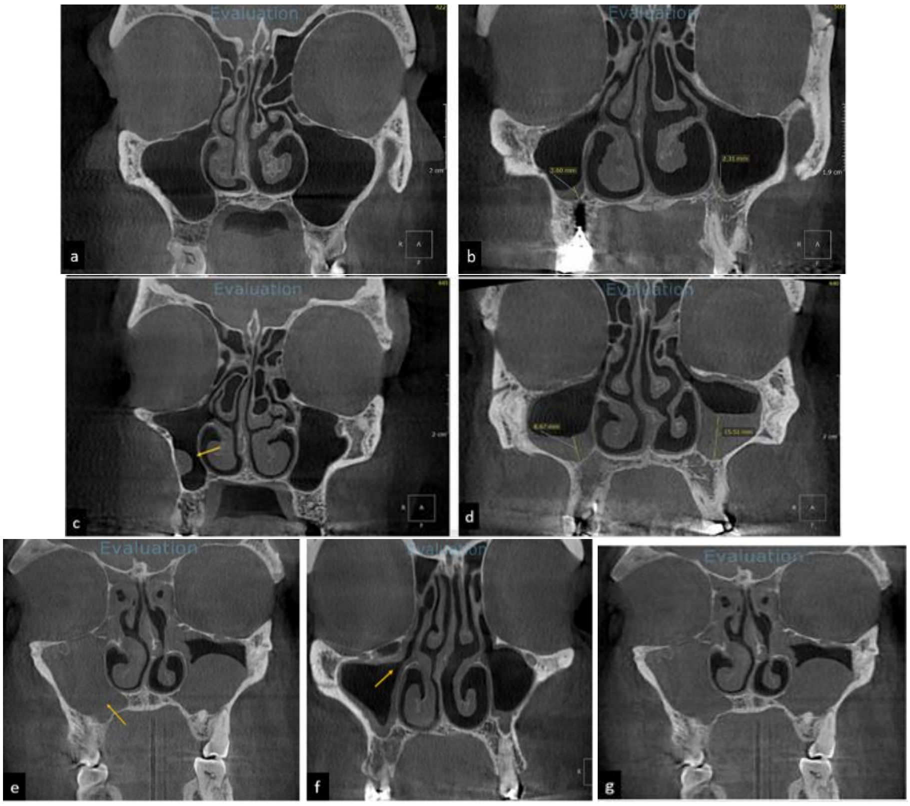

Figure 3: Coronal CBCT images of maxillary sinus and osteomeatal complex shows (a): Normal sinus, (b) Mucosal Thickening,(c) Antral pseudocyst, (d) Partial opacity, (e) Total opacity, (f): Mucosal membrane in ostium, (g): Blocked ostium

Statistical analysis:

All data were entered into a database system and analyzed using SPSS® for Windows version 21 (SPSS Inc., Chicago, IL, USA, 2012). Patient data were analyzed anonymously. Each case was assigned a registration number before evaluation, ensuring explicit and confidential attribution of the required information. A T-test was conducted to investigate the ostium height, the ostium entrance size, and the infundibulum length by sex in an independent sample. Pearson chi-Square test and simple logistic regression analyses were conducted to investigate the relationships among the parameters (including NSD, CB1, CB2, HC1, HC2, MSS1, and MSS2) with age and gender, respectively. For the analysis of anatomical variations, Pearson's chi-square test was used to evaluate the differences in prevalence between male and female patients, as well as between left and right sinuses for each anatomical variation. In cases where the expected frequencies were small, Fisher's exact test was applied to ensure valid statistical inference. P-values < 0.05 were considered statistically significant. To explore the relationship between independent variables, including

Ostium height, length of the infundibulum, size of the ostium entrance, age, gender, left and right sinuses, and anatomical variations on dependent variables (MT, PO, AP, and TO), multiple logistic regression model was used. A multiple linear regression model was used to examine the relationship between these independent variables on the opacity level. The relation between the presence of at least one sinus pathology and nasal septum deviation was investigated using the Pearson chi-Square test while considering the direction of deviation. The level of significance was established at p= 0.05.

Results

Intra-operator reliability

Measurements from the initial and subsequent assessments of 20 patients were recorded, and intra-class correlation coefficients (ICC) were calculated for all measurements. Most measurements showed strong reliability between the first and second replicates, with ICC values ranging from 0.80 to 0.96.

Demographic assessments:

In this study, CBCT images of 200 patients, 138 women (69%) and 62 men (31%), constituted a total of 400 maxillary sinuses, were assessed, as shown in Table 1. Subject age ranged from 18 to 76 years, with a mean age of 37.1 ± 11.54.

Quantitative assessments:

The distribution of ostium variations and infundibulum length according to sinus side and sex is shown in Table 1. No significant difference was found between the two sides of the sinus concerning the ostium height, size of the ostium entry, and infundibulum length. A statistically significant difference was found between gender and ostium height, with men having higher ostium heights ($P < 0.001$). There was no significant relationship between sex and other variables.

Table 1- Distribution of Ostium variations and Infundibulum length by sinus side and Gender

	According to the sinus side				According to Gender			
Variable	**side**	**Mean**	**Std. deviation**	**P value**	**Gender**	**Mean**	**Std. deviation**	**P value**
Ostium Height	Left	31.00	4.88	0.764	Female	30.01	4.28	0.000
	Right	31.16	5.11		Male	33.69	5.62	
Size of the ostium entry	Left	1.59	0.47	0.799	Female	1.78	3.01	0.469
	Right	1.85	3.59		Male	1.56	0.43	
Infundibulum length	Left	7.87	1.73	0.337	Female	7.62	1.58	0.000
	Right	7.82	1.73		Male	8.38	1.94	

Table 2 demonstrates anatomical variations by gender. The chi-square test showed that NSD increased significantly in men ($p < 0.05$), meaning that the odds ratio of having NSD in men was 1.92 times higher than that of women (Table 2). There was a significant difference between genders with CB1 ($p < 0.05$) which was more pronounced was more in women than in men. There was no significant difference between genders with CB2, HC1, HC2, MSS1, and MSS2 ($p > 0.05$).

Table 2- Prevalence of anatomical variations (CB, HC, and MSS) by gender. nasal septal deviation (NSD), unilateral concha bullosa (CB1), bilateral concha bullosa (CB2), unilateral haller cell (HC1), bilateral haller cell (HC2), unilateral maxillary sinus septa(MSS1), unilateral maxillary sinus septa(MSS2)

Variable	**NSD**		**CB1**		**CB2**		**HC1**		**HC2**		**MSS1**		**MSS2**	
Gender	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**
Female	66 (50)	66 (50)	78 (63.4)	45 (36.6)	80 (65)	43 (35)	86 (69.9)	37 (30.1)	96 (78)	27 (22)	90 (73.2)	33 (26.8)	102 (82.9)	21 (17.1)
Male	17 (30.4)	39 (69.6)	39 (81.3)	9 (18.8)	29 (60.4)	19 (39.6)	35 (72.9)	13 (27.1)	36 (75)	12 (25)	38 (79.2)	10 (20.8)	37 (77.1)	32 (18.7)
P-Value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

The prevalence of anatomical variations was assessed in this study. Among 200 examined patients, 105 (55.9%) had deviated nasal septum (NSD). 54 patients (31.6%) had unilateral concha bullosa, and 62 patients (36.3%) had bilateral concha bullosa. Fifty patients (29.2%) had unilateral Haller cells, and 39 patients (22.8%) had bilateral Haller cells. Moreover, 43 patients (25.1%) had unilateral maxillary sinus septum, and 32 (18.7%) had bilateral maxillary sinus septum. Overall, among 200 studied patients (400 sinuses), 52.5% had concha bullosa (50.3% on the left side and 54.8% on the right side), 38% had Haller cells (42.5% of the left sinus and 33.3% of the right sinus), and 31.6% had maxillary sinus septa (33.1% of the left sinus and 29.9% of the right sinus) (Table 3).

Table 3- Prevalence of anatomical variations (NSD, CB1, CB2, HC1, HC2, MSS1, MSS2) by gender

Variable		concha bullosa		Haller cell		maxillary sinus septum	
Gender		**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**	**No (%) n**	**Yes (%) n**
Female	Left	64 (49.6)	65 (50.4)	72 (55.8)	57 (44.2)	85 (65.9)	44 (34.1)
	Right	53 (42.4)	72 (57.6)	88 (70.4)	37 (29.6)	90 (72)	35 (28%)
Male	Left	26 (50)	26 (50)	32 (61.5)	20 (38.5)	36 (69.2)	16 (30.8)
	Right	27 (51.9)	25 (48.1)	30 (57.7)	22 (42.3)	34 (65.4)	18 (34.6)
P-Value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

In the case of concha bullosa (CB), the p-value for the right side was less than 0.05, indicating statistical significance.
The study found a statistically significant result for Haller cells (HC) on the right side, with a p-value of less than 0.05.
For the maxillary sinus septum (MSS), the right side had a p-value of 0.05, indicating statistical significance.
Concerning the relationship between the ostium variations, infundibulum length, and sinus side on the presence of anatomical variations (NSD, CB, HC, and MSS), the ostium size had a significant impact on the presence of HC ($P < 0.001$). No variable significantly affected the presence of CB, and no variable significantly affected the presence of MSS.
A multiple regression model was used to investigate the prevalence of sinus pathologies (MT, PO, capacity rate, presence of mucous membrane, AP) based on gender, sinus, and anatomical variations.
Considering the relationship between the ostium variations, infundibulum length, sinus side, and anatomical variations on mucosal thickening, it was found that MT was significantly higher in men than women ($P < 0.01$). It was considerably higher in people with positive MSS than those without MSS ($P < 0.001$), and there was no significant relationship with other variables (Table 4).
Regarding the relationship between the ostium variations, length of the infundibulum, age, gender, sinus side, and anatomical variations on the amount of opacity rate, it was found that the infundibulum length ($P < 0.001$), age ($P < 0.05$), NSD ($P < 0.05$) and HC ($P < 0.05$) had a significant effect on opacity rate ($p<0.001$). It was observed that age ($P < 0.05$), infundibulum length ($P < 0.05$), and Haller cell ($P < 0.05$) had a significant effect on PO (partial opacity). The odds ratio of positive PO in people with positive HC (Haller cell) was significantly higher than in people with negative HC ($P < 0.05$), and PO was seen in 23% and 14.4% of sinuses with and without Haller cells, respectively (Table 4).
The relationship between ostium height and infundibulum length, ostium size, age, gender, left and right sinus, and anatomical variations on the presence of mucous membrane in the ostium was also investigated. Infundibulum length ($P < 0.01$), gender ($P < 0.001$), ostium height ($P < 0.01$), HC ($P < 0.05$), MSS ($P < 0.01$) and age ($P < 0.05$) had a significant effect on the presence of mucous membrane in the ostium. The odds ratio of having a mucous membrane in the ostium in men (51%) was 4.22 times higher than that of women (22.8%) (Table 4).

Table 4- Distribution of MT, PO, Presence of mucosal membrane based on gender, sinus, and anatomical variations MT (mucosal thickening), Nasal septal deviation (NSD), PO (Partial Opacity), Concha bullosa (CB), Haller cell (HC), Maxillary sinus septa (MSS)

MT		**No (%) n**	**Yes (%) n**	**P-value**
Gender	Female	204 (73.9)	72 (26.1)	0.002
	Male	75 (60.5)	49 (39.5)	
Sinus	Left	139 (69.5)	61 (30.5)	0.878
	Right	140 (70)	60 (30)	
NSD	No	112 (70.9)	46 (29.1)	0.763
	Yes	132 (66)	68 (34)	
CB	No	117 (68.8)	53 (31.2)	0.811
	Yes	127 (67.6)	61 (32.4)	
HC	No	162 (73)	60 (27)	0.713
	Yes	82 (60.3)	54 (39.7)	
MSS	No	184 (75.1)	61 (24.9)	0.000
	Yes	60 (53.1)	53 (46.9)	
PO		**N (%) n**	**Yes (%) n**	**P-value**
Gender	Female	226 (82.2)	49 (17.8)	0.418
	Male	87 (70.2)	37 (29.8)	
Sinus	Left	154 (77.4)	45 (22.6)	0.881
	Right	159 (79.5)	41 (20.5)	
NSD	No	136 (86.6)	21 (13.4)	0.252
	Yes	158 (79)	42 (21)	
CB	No	142 (84)	27 (16)	0.396
	Yes	152 (80.9)	36 (19.1)	
HC	No	190 (85.6)	32 (14.4)	0.042
	Yes	104 (77)	31 (23)	
MSS	No	202(82.4)	43 (17.6)	0.910
	Yes	92(82.1)	20 (17.9)	
Presence of MT in ostium		**No (%) n**	**Yes (%) n**	**P-value**

Table 4- Distribution of MT, PO, Presence of mucosal membrane based on gender, sinus, and anatomical variations MT (mucosal thickening), Nasal septal deviation (NSD), PO (Partial Opacity), Concha bullosa (CB), Haller cell (HC), Maxillary sinus septa (MSS)				
MT		No (%) n	Yes (%) n	P-value
Gender	Female	196 (77.2)	58 (22.8)	0.000
	Male	51 (49)	53 (51)	
Sinus	Left	127 (70.2)	54 (29.8)	0.499
	Right	120 (67.8)	57 (32.2)	
NSD	No	115 (72.8)	43 (27.2)	0.879
	Yes	132 (66)	68 (34)	
CB	No	123 (72.4)	47 (27.6)	0.098
	Yes	124 (66)	64 (34)	
HC	No	165 (74.3)	57 (25.7)	0.021
	Yes	82 (60.3)	54 (39.7)	
MSS	No	180 (73.5)	65 (26.5)	0.008
	Yes	67 (59.3)	46 (40.7)	

Discussion

This study examined the relationship between ostium height, ostium entry size, and infundibulum length, along with anatomical variations and maxillary sinus pathologies, utilizing CBCT images. Furthermore, the prevalence of nasal septal deviation (NSD), concha bullosa (CB), Haller cells (HC), and sinus septa was evaluated. The findings highlighted the significance of evaluating the osteomeatal complex (OMC) and identifying anatomical variations or abnormalities that may impede sinus drainage. Existing studies have shown that disruptions in this passage can contribute to maxillary sinus disorders and related complications for patients.[19]

The present study showed that men had a significantly greater ostium height than women; however, no significant relationship was observed between gender and ostium entry size or infundibulum length. These findings were consistent with those reported by Akay et al. [20]. To our knowledge, no previous research has examined the relationship between sinus dimensions and ostium height, size, and infundibulum length.

Moreover, this study evaluated the presence of mucosal membrane in the ostium region, a parameter not previously analyzed in the literature. It was observed that mucosal membrane presence in the ostium was significantly associated with both infundibulum length and the presence of HCs. Specifically, longer infundibulum length increased the likelihood of mucosal membrane formation, suggesting impaired mucus drainage in this region. Additionally, sinuses with HCs were more prone to mucosal membrane formation, probably due to the proximity of HCs to the ostium. These findings emphasize the need for further research across diverse populations to better understand the implications of mucosal membrane presence in the ostium region.

Nasal septal deviation (NSD) was found in 50% of females and nearly 70% of males, revealing a significant gender difference. This aligned with the study by Akay et al. [15], which reported a higher prevalence of NSD in men. Moreover, a notable correlation was found between gender and unilateral concha bullosa, showing a predominance in females.

In this study, men were 3.13 times more likely than women to develop at least one sinus pathology. Similar gender-related patterns were reported by Akay et al. [15] for left-sided sinus pathology and by Huang et al. [21], who found that men and older individuals were more susceptible to sinus membrane thickening. Ethnic group studies, such as Binshabaib et al. [22], confirmed a higher prevalence of thickened mucosal membranes in men across three populations. These findings indicated that males have a higher risk of developing maxillary sinusitis.

Age also played a significant role, with older individuals more likely to exhibit sinus pathologies. This finding was consistent with studies by Shanbhag et al. [5] and Huang et al. [21], which reported higher mucosal membrane thickening in the elderly. This highlights the need for careful sinus evaluations in older patients.

The relationship between infundibulum length and partial opacification (PO) was also significant, with longer infundibula associated with increased PO likelihood. These results were consistent with Carvalho et al.'s findings, but they contrasted with those of Akay et al. [23], who suggested that shorter infundibula increased PO. Variations may stem from differing inclusion criteria, ethnic diversity, and measurement techniques.

In this study, approximately 10.5% of sinuses exhibited ostium blockage, which aligns with Shanbhag et al.'s [5] reported obstruction rate of 13.1% but contrasts with other studies reporting lower or higher rates. These discrepancies may result from methodological differences, sample size limitations, or random data variations. Ostium obstructions in this study were frequently associated with polyps, while Shanbhag et al. linked them to mucosal membranes exceeding 10 mm.

A significant correlation was observed between HCs and reduced ostium size, suggesting that HCs may contribute to anatomical obstruction. However, Basurrah et al. [24] found no such correlation, though they did observe an association between HCs and longer infundibula, which was not supported by our findings. These differences may reflect varying measurement approaches and population characteristics. Importantly, HC presence was significantly correlated with at least one maxillary sinus pathology, a finding consistent with previous studies.[25,26]

Maxillary sinus septa (MSS) were also linked to increased sinus pathology and mucosal thickening[27]. These results agree with Seluk et al. [28] but contrast with Tassaker et al.[29]. Additionally, MSS can increase the risk of Schneiderian membrane perforation during sinus lift procedures [30], underscoring its clinical significance.

The present study emphasized how infundibulum length, HCs, MSS, gender, and age affect maxillary sinus pathologies. These findings suggested that smaller ostium size and anatomical variations, such as HCs, may predict the risk of mucosal thickening.

Limitations and future directions

This retrospective study did not take into account participants' systemic conditions or medications, which may have impacted the findings. Future research should incorporate these factors and explore longitudinal trends to better understand the progress of sinus pathologies. Increasing sample sizes and incorporating diverse populations will enhance understanding of anatomical variations and their clinical significance.

Conclusion

Factors such as the length of the infundibulum, Haller cells, septa, male gender, and advanced age significantly increase the risk of maxillary sinus pathology. Smaller ostium size is also associated with mucosal thickening. Recognizing these risk factors can help predict sinus issues and enhance surgical planning, especially for elderly patients.

Acknowledgments: Not applicable

Author Contributions:
S.V.: contributed to study idea and design.
M.G.A.: contributed to study design and data collection.
F.F.F.: conducted data collection and analysis.
S.S.A. and S.M.A: conducted manuscript drafting.

Statements and Declarations: The authors also confirmed that the manuscript is original and does not contain any unlawful statements and any material, the publication of which would violate any copyright or other personal or proprietary rights of any person or entity. They also confirm that they have written permission from copyright owners if their work has been used in this manuscript. The authors declare that the following manuscript has not been published elsewhere (in any format or language) and has not been concomitantly sent to another journal for publication consideration. The authors agree that they are responsible for paying any fees for permission.
*This manuscript does not contain any studies with human or animal subjects performed by any of the authors.

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Ethical Approval Code: **IR.SBMU.DRC.REC.1400.137**

Data availability: The data that supports the findings of this study are available from the corresponding author upon reasonable request.

Informed consent: Not applicable

Conflicts of interest/Competing interests: The authors have no relevant financial or non-financial interests to disclose. ■

References

1. Testori T, Wallace SS, Del Fabbro M, Taschieri S, Trisi P, Capelli M, et al. Repair of large sinus membrane perforations using stabilized collagen barrier membranes: surgical techniques with histologic and radiographic evidence of success. Int J Periodontics Restorative Dent. 2008;28(1):9-17.
2. de Carvalho ABG, Ferreira Costa AL, Fuziy A, de Assis ACS, Castro Veloso JR, Coutinho Manhães LRJ, et al. Investigation on the relationship of dimensions of the maxillary sinus drainage system with the presence of sinusopathies: a cone beam computed tomography study. Arch Oral Biol. 2018;94:78-83. doi:10.1016/j.archoralbio.2018.06.021
3. Neugebauer J, Ritter L, Mischkowski RA, Dreiseidler T, Scherer P, Ketterle M, et al. Evaluation of maxillary sinus anatomy by cone-beam CT prior to sinus floor elevation. Int J Oral Maxillofac Implants. 2010;25(2):258-65.
4. Rahpeyma A, Khajehahmadi S. Alveolar Antral Artery: Review of Surgical Techniques Involving this Anatomic Structure. Iran J Otorhinolaryngol. 2014 Apr;26(75):73-8.
5. Shanbhag S, Karnik P, Shirke P, Shanbhag V. Cone-beam computed tomographic analysis of sinus membrane thickness, ostium patency, and residual ridge heights in the posterior maxilla: implications for sinus floor elevation. Clin Oral Implants Res. 2014;25(6):755-60. doi: 10.1111/clr.12168.
6. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006;72(1):75-80.
7. Aryanezhad S-S, Jafari-Pozve N, Abrishami M, Arianezhad SM. Investigating the Anatomy and Location of the Infraorbital Canal in Relation to the Adjacent Structures in Cone Beam Computed Tomography (CBCT) Images. Journal of Maxillofacial and Oral Surgery. 2024. doi: 10.1007/s12663-024-02191-8
8. Al Abduwani J, ZilinSkiene L, Colley S, Ahmed S. Cone beam CT paranasal sinuses versus standard multidetector and low dose multidetector CT studies. Am J Otolaryngol. 2016;37(1):59-64. doi: 10.1016/j.amjoto.2015.08.002
9. Vasegh Z, Safi Y, Azar MS, Ahsaie MG, Arianezhad SM. Assessment of bony changes in temporomandibular joint in patients using cone beam computed tomography–a cross sectional study. Head & Face Medicine. 2023;19(1):47. doi: 10.1186/s13005-023-00392-z
10. Yari A, Hasheminasab M, Fasih P, Nouralishahi A, Arianezhad SM. The pattern of maxillofacial fractures associated with rollover accidents: A 7-year retrospective study. Dent Traumatol. 2024;40(2):213-220. doi: 10.1111/edt.12900
11. Bayrak S, Ustaoğlu G, Demiralp K, Kurşun Çakmak E. Evaluation of the Characteristics and Association Between Schneiderian Membrane Thickness and Nasal Septum Deviation. J Craniofac Surg. 2018;29(3):683-7. doi: 10.1097/SCS.0000000000004254
12. Aramani A, Karadi RN, Kumar S. A Study of Anatomical

Variations of Osteomeatal Complex in Chronic Rhinosinusitis Patients-CT Findings. J Clin Diagn Res. 2014;8(10):Kc01-4. doi: 10.7860/JCDR/2014/9323.4923

13. Lloyd GA, Lund VJ, Scadding GK. CT of the paranasal sinuses and functional endoscopic surgery: a critical analysis of 100 symptomatic patients. J Laryngol Otol. 1991;105(3):181-5. doi: 10.1017/s0022215100115300

14. Sheikhi M, Pozve NJ, Khorrami L. Using cone beam computed tomography to detect the relationship between the periodontal bone loss and mucosal thickening of the maxillary sinus. Dent Res J (Isfahan). 2014;11(4):495-501.

15. Akay G, Yaman D, Karadağ Ö, Güngör K. Evaluation of the Relationship of Dimensions of Maxillary Sinus Drainage System with Anatomical Variations and Sinusopathy: Cone-Beam Computed Tomography Findings. Med Princ Pract. 2020;29(4):354-63. doi: 10.1159/000504963

16. Kaygusuz A, Haksever M, Akduman D, Aslan S, Sayar Z: Sinonasal anatomical variations: their relationship with chronic rhinosinusitis and effect on the severity of disease-a computerized tomography assisted anatomical and clinical study. Indian J Otolaryngol Head Neck Surg. 2014;66(3):260-6. doi: 10.1007/s12070-013-0678-y

17. Valizadeh S, Zafarmand AH, Hassan Yazdi S, Ghazizadeh Ahsaie M. Quantitative Assessment of Posterior Maxillary Arch for Orthodontic Miniscrew Insertion Using Cone Beam Computed Tomography: A Cross-Sectional Analysis. Int J Dent. 2022;2022:8257256. doi: 10.1155/2022/8257256

18. Smith KD, Edwards PC, Saini TS, Norton NS. The prevalence of concha bullosa and nasal septal deviation and their relationship to maxillary sinusitis by volumetric tomography. Int J Dent. 2010;2010. doi: 10.1155/2010/404982

19. Bell GW, Joshi BB, Macleod RI. Maxillary sinus disease: diagnosis and treatment. Br Dent J. 2011;210(3):113-8. doi: 10.1038/sj.bdj.2011.47

20. Akay G, Yaman D, Karadağ Ö, Güngör K. Evaluation of the relationship of dimensions of maxillary sinus drainage system with anatomical variations and sinusopathy: cone-beam computed tomography findings. Medical Principles and Practice. 2020;29(4):354-63. doi: 10.1159/000504963

21. Huang YT, Hu SW, Huang JY, Chang YC. Assessment of relationship between maxillary sinus membrane thickening and the adjacent teeth health by cone-beam computed tomography. J Dent Sci. 2021;16(1):275-9. doi: 10.1016/j.jds.2020.05.002

22. Binshabaib M, SS AL, Alkraida R, Aljared S, Alshami A, Mansour S. Incidental findings in maxillary sinus area on cone-beam-computed-tomographic-scans: A retrospective study with emphasis on gender and ethnicity. Saudi Dent J. 2021;33(4):184-7. doi: 10.1016/j.sdentj.2020.03.002

23. Sandhu R, Kheur MG, Lakha TA, Supriya M, Valentini P, Le B. 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. J Indian Prosthodont Soc. 2020;20(4):371-7. doi: 10.4103/jips.jips_113_20

24. Basurrah MA, Kim SW. Factors affecting dimensions of the ethmoid infundibulum and maxillary sinus natural ostium in a normal population. Saudi Med J. 2021;42(9):981-5. doi: 10.15537/smj.2021.42.9.20210399

25. Khojastepour L, Haghnegahdar A, Khosravifard N. Role of Sinonasal Anatomic Variations in the Development of Maxillary Sinusitis: A Cone Beam CT Analysis. Open Dent J. 2017;11:367-74. doi: 10.2174/1874210601711010367

26. Kamdi P, Nimma V, Ramchandani A, Ramaswami E, Gogri A, Umarji H. Evaluation of haller cell on CBCT and its association with maxillary sinus pathologies. JIAOMR. 2018;30(1):41-5. doi: 10.4103/jiaomr.jiaomr_22_18

27. Balikci HH, Gurdal MM, Celebi S, Ozbay I, Karakas M. Relationships among concha bullosa, nasal septal deviation, and sinusitis: Retrospective analysis of 296 cases. Ear Nose Throat J. 2016;95(12):487-91.

28. Selcuk A, Ozcan KM, Akdogan O, Bilal N, Dere H. Variations of maxillary sinus and accompanying anatomical and pathological structures. J Craniofac Surg. 2008;19(1):159-64. doi: 10.1097/scs.0b013e3181577b01

29. Tassoker M. What are the risk factors for maxillary sinus pathologies? A CBCT study. Oral Radiol. 2020;36(1):80-4. doi: 10.1007/s11282-019-00382-5

30. Çakur B, Sümbüllü MA, Durna D. Relationship among Schneiderian membrane, Underwood's septa, and the maxillary sinus inferior border. Clin Implant Dent Relat Res. 2013;15(1):83-7. doi: 10.1111/j.1708-8208.2011.00336.x