



Are maxillary sinus variations related to maxillary sinus diameters?

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Abstract

Objectives The reasons why the maxillary posterior region is challenging for dentists are its structure and anatomical variations. For this reason, it is necessary to have complete knowledge about the anatomy of this region. In dentistry, necessary information for the desired evaluation in this region can be provided by CBCT. The fact that it provides a three-dimensional evaluation and has measurement reliability emphasizes its importance in surgical applications. The septa, haller cell, and accessory ostium are variations of the maxillary sinus. There are few studies in the literature examining the relationship between maxillary sinus diameters and its variations. The aims of this study are to determine the prevalence of maxillary sinus variations and the average of maxillary sinus diameters, to examine their relationships according to age and gender, and to evaluate the effects of maxillary sinus diameters on variations.

Methods In this retrospective study, CBCT images of 212 patients were examined. The examined CBCT images were analysed and recorded in more than one section. Descriptive statistics, chi-square tests, independent *t* test, one-way Anova tests were used to evaluate the data.

Results As a result, a statistically significant difference was observed between the variations, gender and age groups in terms of morphometric characteristics of the maxillary sinus. The most common variation was observed to be accessory ostium.

Conclusions The rate of patients with at least one anatomical variation was 77.8%. For this reason, a detailed analysis should be performed to avoid complications before surgical procedures are performed in the area.

Keywords Cone-beam computed tomography · Maxillary sinus · Maxillary sinus diameters · Maxillary sinus variation

Introduction

The maxillary sinuses, the largest of the paranasal sinuses, are a pair of bony chambers located within each maxillary bone. Knowledge of maxillary sinus anatomy is important in forensic medicine and various dental and maxillofacial procedures [1].

In today's dentistry, dental implant applications are increasing day by day. The inadequacy of the posterior maxilla crest height, pathologies and variations in the

maxillary sinus have been challenging factors for dentists, especially in elderly patients [2]. The maxillary sinus is a critical anatomical structure for dental implant procedures in the maxilla. Depression of the sinus floor is a common finding that prevents dental implant placement. In such cases, a sinus elevation procedure may be required [3, 4]. Having knowledge about the anatomy of the region before such a surgical operation will reduce the risk of possible complications [5, 6].

While some of the anatomical variations of the paranasal sinuses are known to increase susceptibility to infection, others cause surgical complications. Maxillary sinus septa are one of the variations of the maxillary sinus and originate from the lower and lateral walls of the sinus. The maxillary sinus septa jeopardizes the integrity of the membrane while the sinus floor is being lifted [2, 6–12]. It has been reported that maxillary sinus variations such as accessory maxillary ostium (AMO) and Haller cell (HC) may cause sinusitis [2, 13, 14].

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Implant planning is often complicated due to alveolar ridge atrophy in the posterior maxilla. With the resorption of the crest after tooth loss, the vertical dimension of the crest decreases and maxillary sinus floor elevation is required. The presence of septa in the maxillary sinus affects the sinus elevation processes, as it increases the adhesion force of the Schneiderian membrane [15, 16]. While spiculer process larger than 2.5 mm in the maxillary sinus is considered as septa [17], spiculer process of 2–4 mm is considered as septa in the British literature [18].

The maxillary sinus septa divide the maxillary sinus into two or more parts [19]. Maxillary sinus septa are divided into two according to their development: primary septa caused by congenital differences and secondary septa formed by irregular pneumatization of the maxillary sinus after tooth loss at the base of the maxillary sinus [8, 16, 20]. Sinus septa can occur anywhere in the maxillary sinus walls. Depending on their localization, they are divided into three as anterior, medial and posterior regions. They have been described as follows: anterior region is anterior to the mesial aspect of the first molar; medial region is between the mesial aspect of the first molar and the mesial aspect of the third molar; posterior region is the area distal to the mesial aspect of the third molar tooth. [8, 16, 18].

When the sinus septa are considered as orientation, it is evaluated in three groups as coronal, sagittal and axial, and each group is divided into three in terms of morphology, as an incomplete, completed and completed septa that has formed a separate chamber [17, 21]. Figure 1 shows the septa orientations of the maxillary sinus in three planes (Fig. 1).

The maxillary sinus opens into the posterior part of the infundibulum through its ostium and drains its mucus into the middle meatus on the lateral wall of the nose. Sometimes there is an AMO that opens into the anterior and posterior parts of the inferior turbinate. AMO is considered any extra opening other than the natural ostium of the maxillary sinus. It is usually found in the nasal fontanelle or hiatus semilunaris area [22, 23]. Most authors state that the mucus circulation between the accessory and natural ostium disrupts the drainage of the maxillary sinus, leading to sinusitis [24, 25].

An AMO arises from a membranous region in the medial maxillary wall, located between the uncinat process and the inferior turbinate covered only by the mucoperiosteum. This area is known as the “fontanelle” and has been reported to be potentially perforated by the pressure of pus and edema derived from the recurrence of sinusitis [26].

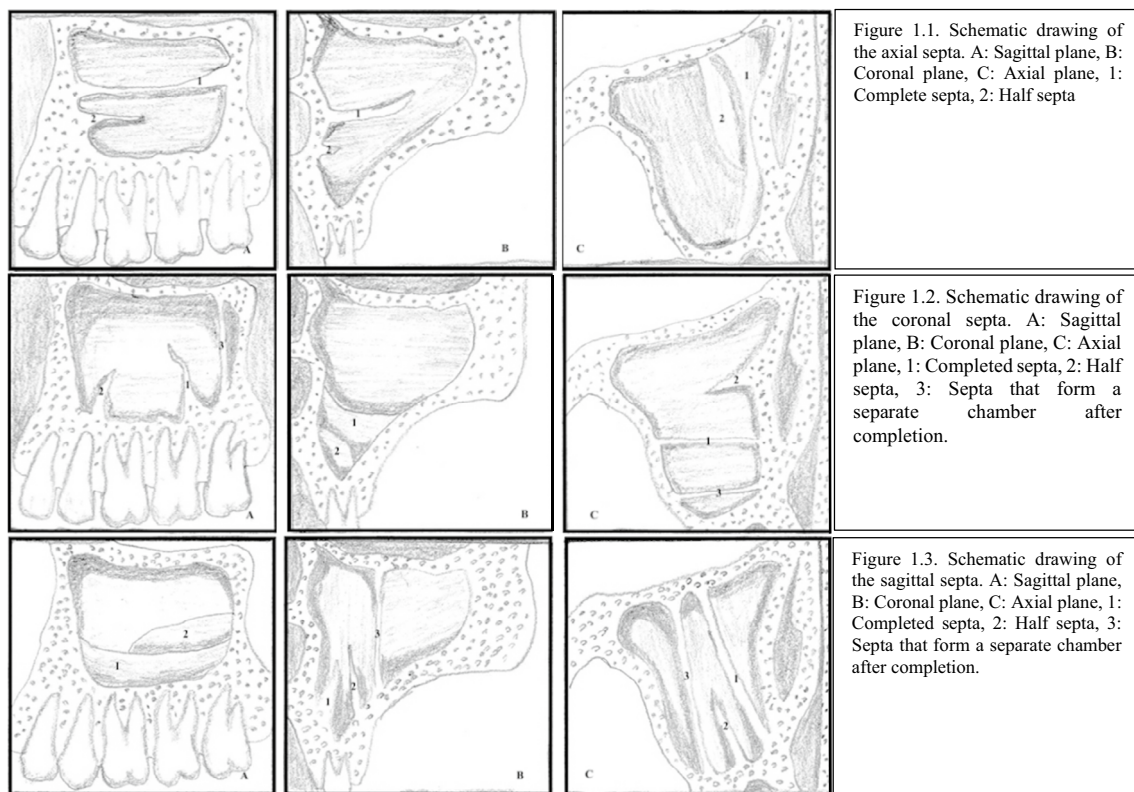


Fig. 1 Schematic drawing of septa orientation types

Accessory maxillary ostium opens to the nasal wall 5 to 10 mm above and laterally from the connection point of the inferior turbinate. AMO is a predisposing factor for chronic maxillary sinusitis. Before the sinus floor lift procedure, surgeons should define the presence and position of the AMO and pay attention to these areas during the operation [27].

Haller cells were first described by Albrecht von Haller. In literature, HC are called infraorbital ethmoid cells or orbito-maxillary cells [29, 30]. Often originated from anterior ethmoid cells, they are defined as ethmoid air cells that extend along the medial part of the orbital floor, near the maxillary ostium [28, 30]. They are formed by the development of anterior ethmoid cells along the roof of the maxillary sinus and the lamina orbita of the ethmoid bone [14, 23, 30–32]. HC, located proximal to the maxillary sinus infundibulum, may cause obstruction of this drainage pathway and sinusitis [2, 14, 28]. This may be manifested by the size of the HCs, the degree of proximity to the infundibulum, or its infection [23, 28, 29, 31]. HCs are thought to be associated with pathologies such as orofacial pain, sinusitis, nasal obstruction, headache, cough, and mucocele [30].

Haller cells are one of the most frequently observed anatomical variations in the osteomeatal complex [33]. Since HC remain lateral to the infundibulum, they are not seen in nasal endoscopy. However, a bulge on the lateral wall below the level of the ethmoidal bulla and narrowness in the infundibulum may suggest the presence of HC [34].

Haller cells have been evaluated with different radiographic techniques such as panoramic radiography, CT, multi-sectional computed tomography, CBCT in the literature. CBCT is an imaging technique that enables the evaluation of paranasal anatomy with a low radiation dose and is suitable for imaging specific to hard tissues [29].

The pneumatization of the maxillary sinus is a physiological process. Its occurrence has been linked to factors such as heredity, bone density, previous sinus surgery, air pressure within the sinus, and extraction of posterior teeth. Pneumatization is remarkable in patients with the extraction of second molars and extraction of two or more adjacent teeth in the posterior maxilla. [35]. In posterior maxilla, a phenomenon, which is a combination of alveolar crest resorption and maxillary sinus pneumatization, is seen after tooth extraction [36]. While maxillary sinus pneumatization causes 30% of alveolar height loss, socket remodeling causes 70% [37].

Direct radiographs (Water's, Cadwell, lateral, basal, oblique and submentovertex), CT, magnetic resonance imaging (MRI), ultrasound and CBCT can be used for the radiological diagnosis of the paranasal sinuses [38].

The development of two-dimensional panoramic imaging techniques began in the first half of the twentieth century.

Since then, this radiographic technique has continuously improved and become the standard for clinicians in daily practice. In parallel with this, in 1982 CBCT was introduced as a tool for dental and maxillofacial diagnoses. Current literature shows that panoramic and intraoral radiographs are the most practical imaging techniques in dentistry [39].

With the introduction of CBCT, a relatively low-dose and high-resolution alternative has been provided for imaging the maxillofacial region. With its low cost, low radiation dose and high spatial resolution, CBCT has become the method of choice for evaluating potential implant sites, especially in complex situations that require three-dimensional views of the area of interest [40–43]. CT and CBCT are considered the gold standard for imaging the sinuses [43]. As well as some advantages over two-dimensional images such as real-size image rendering, CBCT also has advantages over CT such as vertical scanning of the patient in the natural sitting position, isotropic voxel size and less metal artifact. It provides high resolution and accurate size images in a short time. It has lower radiation dose, lower cost and energy efficiency compared to CT. It can be used not only for preoperative evaluations but also for intraoperative evaluations [44]. Because CBCT has isotropic voxels, more accurate and sensitive measurements can be made. Motion artifacts are reduced with fast scanning time. Thanks to artifact-reducing software that works in conjunction with CBCT programs, metal artifacts have decreased significantly and it has become possible to create higher-quality images [45].

The aims of this study are to determine the prevalence of maxillary sinus variations and the average of maxillary sinus diameters, to examine their relationships according to age and gender, and to evaluate the effects of maxillary sinus diameters on variations.

Materials and methods

Ethics committee approval for the study was obtained from the meeting of Selcuk University Faculty of Dentistry, Non-Interventional Clinical Research Evaluation Commission, dated 09.05.2019 and numbered 2019/03. CBCT images in the image archive of Selcuk University Faculty of Dentistry, Department of Oral, Dental and Maxillofacial Radiology were used. CBCT images taken between 01.12.2017 and 19.06.2019 for dental implant planning, determination of impacted tooth position and evaluation of pathological lesions, trauma and cephalometric analysis in orthodontics were included in the study.

Inclusion criteria: CBCT images of patients over 18 years of age, images with all margins of the maxillary sinus present, and images where resolution permits viewing the region. Exclusion criteria: images in which

the entire area to be examined did not enter the image, images of patients who had developmental or neoplastic lesions that would affect the maxillary sinus dimensions and boundaries, trauma and low-quality images. The study included a total of 212 patients (120 male and 92 female) between the ages of 18–90 (mean 50.2 ± 15.6 years), and evaluated 424 maxillary sinus images. Before examining the relationship of variations of the maxillary sinus with age, the ages of the patients were divided into groups ($\dots < 35$, $35 \leq \dots < 50$, $50 \leq \dots < 65$, $65 \leq \dots$). Patients who lost all their premolar and molar teeth were classified as the posterior edentulous group. Since the number of patients with all posterior teeth was scarce in our sample group, patients who lost only one of their premolar or molar teeth were classified as the dentate group. Of the 424 quadrants, 200 were edentulous, while 224 were dentate.

All cone-beam computed tomography data used in the study were obtained using CBCT (Instrumentarium Dental, Palo DEx Group Oy Nahkelantie 160 FI-04300 TUUSULA, Finland) at the Oral, Dental and Maxillofacial Radiology clinic using 89 kVp, 4–12 mA values. The measurements were made by the same observer on a BenQ GL2460 (24 inch, 1920X1080 resolution) model screen, repeated three weeks apart. The parameters

examined using 0.5 mm section thickness were vertical, sagittal and horizontal diameters of the maxillary sinus, maxillary sinus septa, AMO and HC.

A technique used by Akhlaghi et al. were applied for maxillary sinus diameters (Fig. 2) [46, 47].

Maxillary sinus diameters and measurements

Maximum horizontal (transversal) diameter, also called the width of the maxillary sinus, is measured by the distance between tangents passing through the deepest points of the lateral and medial walls of the maxillary sinus.

Maximum vertical (cranio-caudal) diameter, also called the height of the maxillary sinus, is measured by the distance between the tangent lines passing through the deepest point of the inferior wall and the highest point of the superior wall of the maxillary sinus.

Maximum sagittal (antero-posterior) diameter, also called the length of the maxillary sinus, is measured by the distance between the tangents passing through the deepest points of the anterior and posterior walls of the maxillary sinus [47–49].

The vertical diameter of the maxillary sinus was greatest in the region of the first molar. The horizontal, vertical and



Fig. 2 Measurement of the vertical (VD). Horizontal (HD) and sagittal diameters (SD) of the maxillary sinus

Fig. 3 Hall cells (H). Accessory ostium (white arrows). uncinat process (U). Inferior concha (IC). Medial concha (MK) seen in coronal planes





Fig. 4 Septa types and orientations. **A, B, C** axial septa images in axial. Coronal and sagittal planes. **D, E, F** coronal septa images in axial. Coronal and sagittal planes. **G, H, I** sagittal septa images in axial. Coronal and sagittal planes, respectively

sagittal diameters of the maxillary sinus in adults were around 25–35, 36–45, and 38–45 mm, respectively [37, 50].

While examples of HC and AMO encountered in the study are shown in (Fig. 3), examples of septa and septa orientations are shown in (Fig. 4).

In our study, the position, number, orientation and morphology type of septa were noted and statistical analysis was performed. It is necessary to examine CBCT images in at least two planes to determine the orientation of the septa and the type of orientation. Coronal and sagittal planes were examined for axial septa, axial and sagittal planes were examined for coronal septa, and axial and coronal planes were examined for sagittal septa.

The data obtained from the images were saved in the Microsoft Excel program. Statistical analysis was performed with IBM SPSS version 26 (Mac Os). Maximum, minimum, mean and standard deviation values of continuous data and frequency and percentage values of categorical data

were obtained by descriptive statistics. The relationship of maxillary sinus diameters with gender and variations was analysed by independent *t* test, and the relationship with age groups was analysed by a one-way ANOVA test. The relationship between maxillary sinus variations and dental status was analysed by the chi-square test. $p < 0.05$ was considered statistically significant.

Results

Our study was performed using CBCT images of 424 maxillary sinuses in 212 patients. While 165 (77.8%) variations were observed in 212 patients, the most common variation was the AMO (122 patients, 57.5%) and the least observed variation was the HC (51 patients, 24.1%). In our study, the septa were seen in 89 (42%) patients and in 128 maxillary sinuses (30.2%) (Table 1).

Table 1 Frequency table of maxillary sinus variations

		n (212 patient)		n (424 MS)	
			%		%
Variation	Present	165	77,8	277	65,3
	Absent	47	22,2	147	34,7
	Total	212	100	424	100
Haller cell	Present	51	24,1	70	16,5
	Absent	161	75,9	354	83,5
	Total	212	100,0	424	100
Accessory Ostium	Present	122	57,5	203	47,9
	Absent	90	42,5	221	52,1
	Total	212	100,0	424	100
Septa	Present	89	42,0	128	30,2
	Absent	123	58,0	296	69,8
	Total	212	100,0	424	100

Bold emphasizes the frequency of haller cell, accessory ostium, and septa

The frequency distributions for the axial, coronal and sagittal septa orientations and their 3 types (incomplete/completed/completed and formed a separate chamber) were as in (Table 2). The most common septa orientation was coronal type (132 maxillary sinuses, 88%). The most common morphology type (valid for all septa orientation types) was the completed septa type. In our study, complete septa type that was completed and formed a separate chamber in sagittal and axial plane were not observed (Table 2).

In our study, the septa position was most frequently observed in the middle part while least commonly observed in the posterior region (Table 2).

The minimum, maximum and mean values of the maxillary sinus diameters are shown in (Table 3). The mean vertical, horizontal and sagittal diameters of the maxillary sinus are 36.36, 23.30 and 37.12 mm, respectively (Table 3).

Table 4 shows the relationships between the vertical, horizontal and sagittal diameters of the maxillary sinus and the AMO, septa, HC, gender and dental status. There is a statistically significant difference between the diameters of the maxillary sinus in three dimensions and gender ($p < 0.05$). Accordingly, the maxillary sinus diameters of men are larger than the sinus diameters of women. In the statistical tests, a statistically significant result was found between the diameters of the maxillary sinus and the septa, AMO and HC ($p < 0.05$). Maxillary sinus diameters are larger in the presence of AMO, HC and septa, but smaller in the absence of them. A statistical relationship was found only between the sagittal diameter of the maxillary sinus and the posterior dental status. It was observed that the mean maxillary sinus sagittal diameters of patients with posterior teeth were larger than those of posterior edentulous patients (Table 4).

Anova test was applied to examine the relationship between maxillary sinus diameters and age groups. After the result was found statistically significant, post-hoc analyses were performed. Accordingly, no statistical significance was found between the vertical diameter of the maxillary sinus and the age groups. Statistically significant difference was found between the horizontal and sagittal diameters and age

Table 2 Septa orientation, type of orientation and distribution of septa position in the right-left maxillary sinus

Septa orientation	Orientation type	n	% (Total)	Septa localization	n	%	
Axial	Half septa	6	4,0	Right	Anterior	19	28,0
	Completed septa	8	5,3		Middle	36	52,9
	Completed and formed a separate chamber	0	0,0		Posterior	13	19,1
Coronal	Half septa	26	17,3	Left	Anterior	23	28,0
	Completed septa	103	68,7		Middle	43	52,4
	Completed and formed a separate chamber	3	2,0		Posterior	16	19,6
Sagittal	Half septa	1	0,7	Total (Patient)	Anterior	42	28,0
	Completed septa	3	2,0		Middle	79	52,7
	Completed and formed a separate chamber	0	0,0		Posterior	29	19,3

Table 3 Descriptive statistics of maxillary sinus diameters

	Minimum(mm)	Maximum(mm)	Mean(mm)	Standard deviation(mm)
Vertical diameter	15	54	36.36	6.63
Horizontal diameter	8	36	23.30	4.49
Sagittal diameter	19	36	37.12	4.19

Table 4 Relationship of maxillary sinus diameters with gender and variations

			Ort. ± S.D (mm)	<i>p</i>	
Accessory Ostium	Vertical diameter	Present	36.98 ± 6.16	0.022*	
		Absent	35.40 ± 6.94		
	Horizontal diameter	Present	23.81 ± 4.21	0.007*	
		Absent	22.68 ± 4.78		
	Sagittal diameter	Present	37.46 ± 3.87	0.001*	
		Absent	36.62 ± 4.54		
	Septa	Vertical diameter	Present	36.39 ± 6.18	0.016*
			Absent	35.85 ± 6.77	
Horizontal diameter		Present	23.78 ± 4.27	0.013*	
		Absent	23.00 ± 4.62		
Haller cell	Vertical diameter	Present	38.60 ± 5.61	0.001*	
		Absent	35.58 ± 6.66		
	Horizontal diameter	Present	24.81 ± 3.77	0.001*	
		Absent	22.86 ± 4.65		
Gender	Vertical diameter	Male	38.85 ± 6.14	0.000*	
		Female	32.99 ± 5.50		
	Horizontal diameter	Male	24.19 ± 4.18	0.000*	
		Female	22.20 ± 4.64		
	Sagittal diameter	Male	37.87 ± 3.87	0.000*	
		Female	36.10 ± 4.37		
	Dental Status	Vertical diameter	Dentate	36.57 ± 6.69	0.379
			Edentulous	36.01 ± 6.39	
Horizontal diameter		Dentate	23.52 ± 4.38	0.346	
		Edentulous	23.11 ± 4.61		
Sagittal diameter	Dentate	37.80 ± 4.03	0.000*		
	Edentulous	36.33 ± 4.22			

Independent *t* test was used

* *p* < 0.05 was considered statistically significant

groups. It was observed that the mean horizontal diameter of the 18–35 age group was greater than the mean horizontal diameter of the 50–65 age group. No statistical difference was found between other age groups in this diameter. It was observed that the mean sagittal diameter of the 65 + age group was larger than that of the 50–65 age group, and there was no statistical difference in this dimension between the other age groups (Table 5).

As seen in Table 6, which shows the relationship between maxillary sinus variations and age group and gender, no statistical relationship was observed between the variations and gender and age groups (Table 6). Table 7 shows the relationship between maxillary sinus variations and dental status. Among the parameters shown in Table 7, septa and HC seem to be associated with dental status.

Discussion

The maxillary sinus is an important anatomical structure for maxillofacial surgery. Examination of this area before the surgical procedure gives the surgeon valuable information to prevent complications that may occur during the operation [28]. The success of sinus floor elevation operation is a procedure dependent on fragile anatomical structures and variations [10]. Even though sinus floor elevation procedure has complications such as perforation of the Schneiderian membrane, it has become a very reliable technique. The presence of maxillary sinus septa can cause accidental perforation of the Schneiderian membrane during the procedure and then the development of acute or chronic sinusitis and eventually graft resorption. In addition, the septa can be an obstacle to the elevation of the bone plate and sinus membrane during surgery. It is thought that

Table 5 Relationship between maxillary sinus sizes and age groups

	Age groups	N (424 MS)	Ort. ± S.D (mm)	<i>p</i>
Vertical diameter	... < 35	80	37.2 ± 6.63	0.072
	35–50	110	35.51 ± 6.21	
	50–65	172	35.87 ± 6.77	
	65 +	62	37.77 ± 6.14	
Horizontal diameter	... < 35	80	24.35 ± 4.17	0.001*
	35–50	110	23.02 ± 4.12	
	50–65	172	22.52 ± 4.68	
	65 +	62	24.81 ± 4.46	
Sagittal diameter	... < 35	80	37.81 ± 3.51	0.001*
	35–50	110	37.18 ± 4.33	
	50–65	172	36.25 ± 4.41	
	65 +	62	38.42 ± 3.56	

One-way Anova test and Post-hoc analyses (LSD) were used

* $p < 0.05$ was considered statistically significant

maxillary sinus variations may predispose to infection. Hall cells can narrow the drainage pathway in the osteomeatal complex. AMO may disturb the mucociliary clearance of the maxillary sinus. The person who has HC or AMO is vulnerable to inflammatory sinus diseases [14, 27].

CT and panoramic radiographs are the most commonly used radiological methods for dental implants. It has been shown that CT is a more reliable radiological method than panoramic radiographs in previous studies. With the recent introduction of CBCT, the use of CBCT in maxillofacial imaging has increased. CBCT has become more popular in maxillofacial imaging because the radiation dose is less, it is cheaper and it produces less metal artifact than CT [6]. Paranasal sinus variations and anatomy should be well known for minimally invasive surgical techniques. Anatomical variations should be well known and visualized before the operation to avoid complications that may occur during surgical procedures and to perform the operation safely. Compared with two-dimensional imaging techniques,

CT has been reported to be a more reliable technique for mucosal changes in the sinuses. CT and CBCT are generally accepted as the gold standard for radiographic imaging of the sinuses [40, 43]. For these reasons, CBCT images were used in our study.

Sinus membrane perforation is the most common complication in surgical procedures of patients with sinus septa. Since surgical applications involving the maxillary sinus segment have become more frequent, radiological evaluations that determine the size and localization of the septa have gained importance [8]. In this study, the septa were evaluated retrospectively with CBCT images. The prevalence of septa in this study was 42%. A wide range of septa prevalence such as 6.4–66.5% has been reported in the literature [5, 7–12, 14–18, 20, 23, 27, 50]. It has been reported that the incidence of septa varies in studies conducted in different societies. The frequency of septa observed in our study is consistent with the literature. The wide range of its incidence is explained by racial factors [19].

Sinus septa is an anatomical variation of the sinus cavity for which surgical intervention is usually not required. In recent years, data on the clinical importance of the orientation and location of the septa have drawn attention

Table 7 Relationship of maxillary sinus variations with dental status

		Dental Status (%) (<i>n</i> = 424MS)		<i>p</i>
		Dentate	Edentulous	
Haller cell	Present	45 (10.6)	25 (5.9)	0.036*
	Absent	179 (42.2)	175 (41.3)	
Accessory ostium	Present	109 (25.7)	94 (22.2)	0.733
	Absent	115 (27.1)	106 (25)	
Septa	Present	78 (18.3)	50 (11.8)	0.028*
	Absent	146 (34.4)	150 (35.5)	

Chi-square tests were used

* $p < 0.05$ was considered statistically significant

Table 6 Relationship of maxillary sinus variations with age groups and gender

		Age groups (%) (<i>n</i> = 212 patient)				<i>p</i>	Gender (%)		<i>p</i>
		... < 35	35–50	50–65	65 +		Male	Female	
Haller cell	Present	14 (6.6)	13 (6.1)	20 (9.4)	4 (1.9)	0.198	33 (15.6)	18 (8.5)	0.180
	Absent	26 (12.3)	42 (19.9)	66 (31.1)	27 (12.7)		87 (41.0)	74 (34.9)	
Accessory Ostium	Present	25 (11.8)	35 (16.5)	43 (20.3)	19 (9.0)	0.330	73 (34.4)	49 (23.1)	0.269
	Absent	15 (7.1)	20 (9.4)	43 (20.3)	12 (5.6)		47 (22.2)	43 (20.3)	
Septa	Present	20 (9.5)	24 (11.4)	33 (15.6)	12 (5.7)	0.64	44 (20.8)	45 (21.2)	0.092
	Absent	20 (9.5)	31 (14.6)	53 (25.0)	19 (9.0)		76 (35.9)	47 (22.1)	

Chi-square tests were used

$p < 0.05$ was considered statistically significant

in the literature. With these data, it is thought that the sinus floor elevation procedure may reduce complications due to increased use [51]. In our study, the septa orientation type was most common in the coronal direction. In studies on the characteristics of the septa in the literature, the sinus septa were mostly observed in the coronal plane, in line with our study [10, 11, 16, 17, 21, 27]. Although they used a different classification when Kocak et al. and Lozano-Carrascal et al. classified the septa orientation, they reached a similar conclusion to us [10, 21]. The sinus septa can extend along the wall where it is formed, or it can form in incomplete, and it can also extend to all walls in three dimensions. In our study, the most common type was the completed type of septa and it was mostly seen in the middle part of the sinus floor. This result was also observed to be compatible with the literature [11, 17, 21].

While Zinreich and Kennedy defined the HC as the air cell located lateral to the infundibulum, adhering to the roof of the maxillary sinus and inferior to the ethmoid bulla, Bolger et al. defined it as the air cells located in the lower part of the lamina papyracea, including the air cell in the ethmoid infundibulum, under the ethmoid bulla and in the roof of the maxillary sinus [32]. In this study conducted with CBCT, the prevalence of HC was found to be 24.1%. Literature review showed that the prevalence of HC is between 8 and 39% [13, 14, 23, 28, 30, 31, 33, 34, 52]. It was observed that the result of this study was consistent with the range in the literature. However, when these studies were examined, it was noticed that there were differences even in the same race, which is thought to be due to regional and ethnic factors, as well as differences in the interpretation of HCs.

It is recommended to elevate the membrane towards the medial wall of the sinus, during sinus floor elevation. There are several reasons for this. The first is the blood supply provided by the posterior lateral nasal artery on the medial wall. The second is the fact that the membrane on the medial wall reduces the tension of the elevated membrane. However, although it is recommended to elevate the membrane towards the medial wall, attention should be paid to the AMO on the medial wall [27]. In our study, the prevalence of AMO was found 57,5%. In studies conducted in the literature, a prevalence was found in the range of 1.9–45.5%. The study conducted by Young et al. found the closest result to this study with a prevalence of 45.5% [13, 14, 24–27]. In the information gathered from the literature, nasal septum deviation is among the factors affecting the formation of the AMO. This study was conducted without considering nasal septum deviation. In the literature, it has been thought that there may be other variables that may affect the formation of the AMO, such as infections, minor nasal traumas in childhood and genetic factors [24]. Not examining these factors is one of the limitations of this

study. Therefore, we suggest that these factors should also be examined in future studies about AMO.

In this study, the relationship between maxillary sinus variations and dental status was examined. While there is a statistically significant relationship between dental status with septa and HC, there is no statistically significant relationship with AMO. Dedeoglu and Altun found a higher frequency of AMO in posterior edentulous patients. It is thought that the reason for this difference may be due to other factors such as inflammatory pathologies of the maxillary sinus. Although there is no statistically significant relationship in some of the studies examining the relationship between septa and posterior dental status in the literature [2, 49], there are also studies that found statistically significantly higher frequency of septa in edentulous patients [16]. In this study, septa and HC were found with a higher frequency in patients with posterior teeth. It is thought that the reason for these differences may be due to methodological differences in the studies and genetic factors. It is thought that the methodological difference can be eliminated by increasing the number of patients. Dedeoglu and Altun did not find a statistically significant relationship between HC and posterior dental status. In this study, the frequency of HC in posterior edentulous patients was statistically higher in posterior edentulous patients. It is thought that genetic factors may play a role in this difference.

The vertical, horizontal and sagittal lengths of the maxillary sinus were measured and the relationship between them and the maxillary sinus variations was examined. Accordingly, a statistically significant relationship was found between these lengths and septa, HC and AMO. The mean maxillary sinus diameters of images with maxillary sinus variation were statistically significantly larger in all three planes. In this study, the relationship between maxillary sinus diameters and posterior dental status is also examined. There was only one statistically significant result and that was between sagittal diameter and posterior dental status. According to this result, sagittal diameter decreases statistically significantly after tooth extraction. To provide more support for the prosthesis to be made after tooth extraction and to preserve the dimensions of the maxillary sinus, we recommend that the prosthesis construction should not be postponed for a long time. The literature was reviewed in terms of the relationship between maxillary sinus diameters and maxillary sinus variations. Only one article was found that was conducted by Cakur et al., who examined the relationship between sinus height and the presence of septa and it is observed that there was no statistically significant relationship between them [50]. However, when the material and method part of the study was examined, it was observed that the maxillary sinus measurement technique was different. Creating a standard

for the measurement of maxillary sinus diameters will eliminate the method differences in future studies. No article was found in which other diameters were associated with variations. Our study is thought to be the first in this regard. It is thought that this study can be a guide for future articles on this subject.

Maxillary sinus diameters were compared with gender and age groups, and a statistically significant relationship was found between them. It was observed that men have larger sinus diameters than women. The literature has associated the gender difference in maxillary sinus sizes with men's body height and weight, which are generally larger than women's [49].

When the age groups were examined, it was observed that there was no statistically significant difference in the vertical diameter, but there were statistically significant differences in the other diameters. It was observed that the mean maxillary sinus diameter of the patients aged 18–35 years in the horizontal diameter was larger than those aged 50–65 years. It was also observed that the mean maxillary sinus diameter of patients over 65 years of age in sagittal diameter was greater than those between 50 and 65 years of age.

Conclusion

A limited Turkish population was evaluated in our study which examined the variations and diameters of the maxillary sinus. At least one variation was observed in 165 (77.8%) of 212 patients (at least one variation in 278 of 424 maxillary sinuses). AMO (57,5%) and septa (42%) were observed in a substantial amount. The most common type of orientation observed within the septa of the maxillary sinus was the completed coronal type. Septa was most frequently observed in the middle part. When the dimensional diameters of the maxillary sinus were examined, it was statistically determined that the values of male patients were higher than females.

In this current study, the relationship between maxillary sinus diameters and maxillary sinus variations are examined. In this regard, the number of studies are lacking in the literature. According to the results of this study, patients with maxillary sinus variation had higher maxillary sinus diameters. Therefore, it should be considered that there may be a variation if the maxillary sinus diameter is higher than its average values. Additionally, the fact that maxillary sinus diameters are higher in males is thought to be useful information for forensic science.

Considering that maxillary sinus variations with such a high incidence may cause complications in sinus surgeries, preoperative CBCT imaging is essential. Dentists should not ignore the variations in surgical interventions to be applied

to the posterior maxilla, especially the maxillary sinus, to prevent complications, and should benefit from radiography methods that allow the evaluation of all three dimensions (where indicated).

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Declarations

Conflict of interest The author(s) declare no competing interests.

Ethical approval All procedures followed were in accordance with the Ethical Standards of the Responsible Committee on Human Experimentation (Institutional and National) and with the Helsinki Declaration of 1975, as revised in 2008.

Informed consent Informed consent form was not obtained as it was a retrospective study.

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