

Evaluation of maxillary sinus septa: a retrospective clinical study with cone beam computerized tomography (CBCT)

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Abstract. – OBJECTIVE: To determine the prevalence, height, location, orientation, and type of maxillary sinus septa in atrophic, non-atrophic, and partially atrophic maxillary segments using cone beam computerized tomography (CBCT).

PATIENTS AND METHODS: This cross-sectional study was conducted on a retrospective evaluation of CBCT images of 1000 maxillary sinus with 500 subjects from December 2009 to December 2012. The differences among gender, left and right side of maxillary sinus, type of crest and feature of septa were statistically analyzed.

RESULTS: A total of 297 septa was recorded in 1000 maxillary sinuses (29.7%) with a mean height was 4.62 ± 2.50 mm. Forty-four (8.7%) septa were located in the anterior area, 123 (24.5%) in the middle area, and 131 (26.4%) in the posterior area. Seventy maxillary sinus septa (26.1%) were observed with a mediolateral type orientation. There were no significant differences between all features of maxillary sinus septa and gender or type of crest. The only significant association identified was between type of crest and type of septa.

CONCLUSIONS: The maxillary sinus septa exhibited variable characteristics according to orientation and type of crest. CBCT analysis is very important and should be performed before maxillary sinus surgery to prevent possible complications.

Key Words:

Tomography, Sinus, Anatomy, Radiology, Humans.

Introduction

Dental implants are increasingly used to restore partially and complete edentulism¹. However, installation of osseointegrated implants in the maxillary posterior area is complicated by the presence of the maxillary sinus above the surgical

site². After the loss of posterior molar roots on the floor of the maxillary sinus, osteoclastic activity increases and bone resorption results in further expansion of the inferior aspect of the sinus. The resorption of alveolar bone and pneumatization of the sinus cavity often results in inadequate bone height for dental implant surgery^{2,3}. Depending on anatomical limitations, sinus augmentation is often required to elevate the sinus floor to increase the vertical height, prior to successful placement of dental implants⁴. Anatomical variations of the maxillary sinuses such as the presence of septa, especially along the inferior wall, may cause complications during sinus floor elevation surgery. Therefore, radiological evaluation prior to lateral window preparation or osteotome sinus lift approaches is very important to diagnose the presence of septa⁵. Since the design of the lateral window technique is based on the presence and size of the maxillary sinus septa⁶, accurate detection of septa may affect the location of the window during external sinus and internal sinus floor elevation surgery. Further, because the Schneiderian membrane is tightly adherent along the location of the septa, there is an increased risk for perforation during the lifting procedure⁷. Sinus septa was first defined by Sakhdari et al⁷ in 1910. This report classified septa according to their location relative to teeth and septa were divided into 3 groups: anterior, middle and posterior septa. However, other studies have reported variations in their presence. Sakhdari et al⁷ reported an incidence rate of 44.8%, whereas Jang et al⁸ reported a prevalence of 25.8% among edentulous patients and 27% in dentate patients. Krennmair et al⁹ further classified septa based on the degree of pneumatization: primary and secondary septa. Primary septa arise from the development of

the maxilla, whereas the secondary septa are said to arise from the irregular pneumatization of the sinus floor following tooth loss. Maxillary sinus septa have also been classified according to their orientation such as mediolateral, transverse, and sagittal¹⁰. Previous studies mostly focused on the existence of maxillary sinus septa and on septa in edentulous arches by radiological photographs^{11,12}. Little is known concerning the characteristics of sinus septa. Aims of this study were: (1) to measure variables related to the sinus septa (prevalence, numbers, heights, locations, type, and orientations) on reconstructed cone beam computerized tomography (CBCT) images; (2) to determine whether differences in these characteristics exist based on gender; (3) to compare the maxillary septa according to type of crest in addition to comparing the right and left sinuses using CBCT.

Patients and Methods

Patients

This study was approved by the Institutional Review Board (Approval number: 971328527050.01.04) and was conducted on a retrospective evaluation of CBCT images of 1000 maxillary sinus from 500 subjects (224 females, 276 males, with a mean age of 41.24 ± 15.37 ranging from 18 to 86 years). These CBCT images were obtained from patients who visited the Department of Dento-Maxillofacial Radiology, Dicle University (Diyarbakir, Turkey) from 2009 to 2012. Patients, who were seeking dental and/or oral treatments (i.e. dental implants, endodontic procedures, oral/periodontal surgery, orthodontics and oral diseases), were included. Exclusion criteria consisted of the presence of metallic artifacts, sinus pathology, jaw fracture, grafted sinuses, and non-diagnostic, low-resolution quality of CBCT images. One hundred thirty-four patients (26.8%) were completely edentulous, 220 patients (44%) were non-edentulous, and 146 patients (29.2%) were partially edentulous. The CBCT scans were evaluated to detect the features of septa such as presence and number of septa, their height, location, type, and orientation. All of these parameters were recorded from the right and left maxillary sinuses.

CBCT Image Analysis

The CBCT images were obtained by using a CBCT scanner (I-CAT vision TM Imaging Science International, Hatfield, PA, USA) at 120 kVp

and 18.54 mA, with an exposure time of 8-9 s. The voxel size of the images was 0.25-0.4. Image analysis was performed on the KaVo Three Dimensional (3D) eXam Vision (KaVo Dental GmbH, Biberach/Riss, Germany) software, on a multiplanar reconstruction window in which the axial, coronal, and sagittal planes, could be visualized in 0.2 mm intervals. All the images were reviewed and all the measurements were performed by one calibrated examiner (T.T.Y.).

CBCT Analysis Method

Demographic patient data was recorded. At least 2.5 mm in height of cortical bone was considered for the threshold value to identify septa⁷ (Figure 1). Axial, coronal, sagittal, panoramic, and 3D images were assessed for detection of maxillary sinus septa (Figure 2-4). The axial and sagittal images were used to determine the localization of septa relative to the teeth. The location of the maxillary sinus septa was classified into 3 classes as previously described⁷: class 1: anterior; class 2: middle; class 3: posterior. Anterior one third extended from anterior wall of the sinus to the distal aspect of the second premolar, whereas the middle one third was classified as the area from the distal aspect of the second premolar to the distal aspect of the second molar. The posterior one third extended from the distal aspect of the second molar to the posterior wall of the sinus. Sagittal images were used to determine the height of septa⁸ (Figure 1). The type of septa was divided into two classes as described previously²: class 1: primary (a septum located apically to the maxillary root at the dentate site); class 2: other (a septum located apically to an edentulous ridge). Orientation of the maxillary sinus septa was classified into three classes¹⁰: class 1: mediolateral; class 2: sagittal; class 3: transverse. The mediolateral type displayed in the buccopalatal direction in the arch connects the buccal and palatal floors. The sagittal type displayed parallel to the orientation sagittal plane. The transverse type displayed parallel to the sinus floor¹⁰ (Figure 2). An atrophic maxillary dental ridge was defined according to the presence or absence of teeth as: missing (1st, 2nd, and 3rd molars missing), non-atrophic (1st and 2nd molars present), and partially atrophic (between atrophic and non-atrophic)⁴. The groups were defined according to different study variables, such as gender, according to dentate status, and the number, location, and orientation of each septum. Furthermore, differences in the prevalence rates of septa between male and female groups, right and left side, and between the atrophic, partially

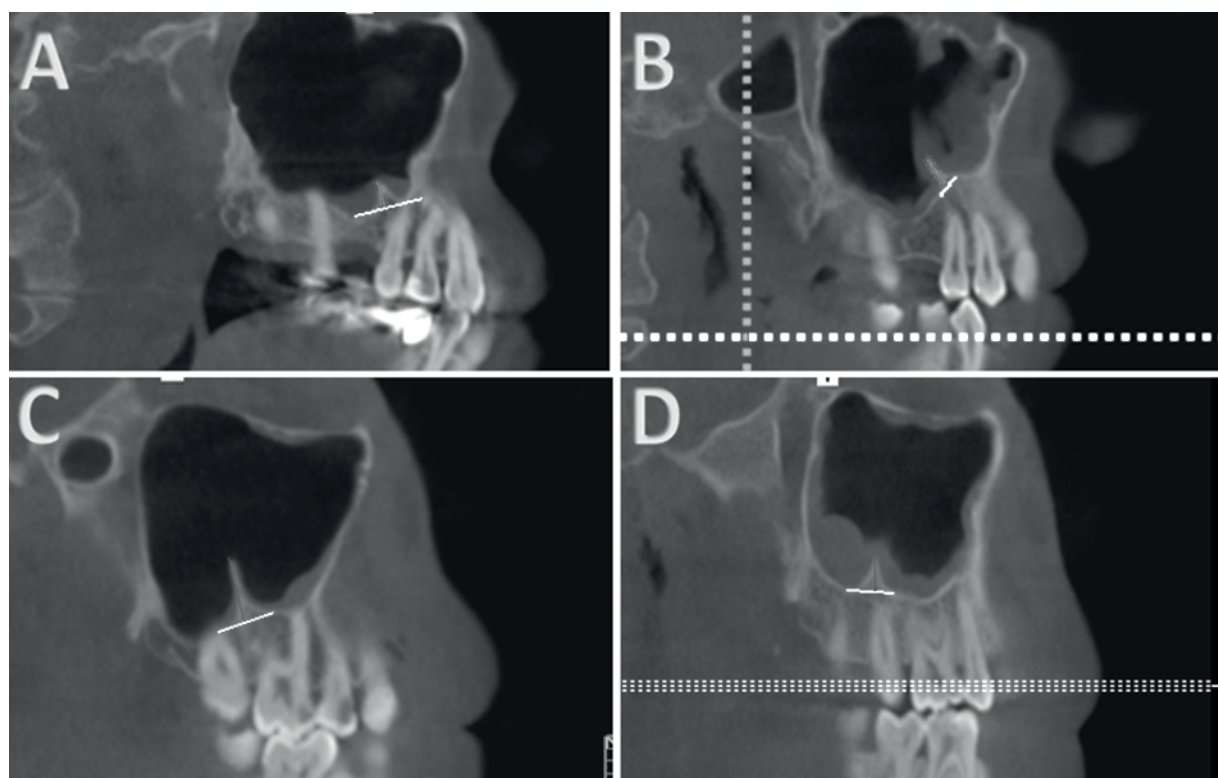


Figure 1. Measurement of height of maxillary sinus septa in sagittal views. *A-B*, Measurement of height of maxillary sinus septa in anterior region *C-D*, Measurement of height of maxillary sinus septa in middle region.

atrophic, and non-atrophic groups, were determined¹⁰.

Statistical Analysis

SPSS 23.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. χ^2 -test was used to detect whether there were significant differences in the prevalence, height, location, type, and orientation of the septa in the atrophic, partially atrophic, non atrophic groups and in the prevalence of the septa by gender and in both left and right sinuses. p -values less than 0.05 were considered statistically significant.

Results

Prevalence

A total of 1000 maxillary sinuses from 500 subjects were examined. In total, 297 septa were recorded in 1000 maxillary sinus (29.7%), which corresponded a prevalence rate of 27.2% in this study population. Of these, 162 (29.4%) were identified in male patients, while 135 (30.1%) were found in female patients. The prevalence of

septa in atrophic, partially atrophic, and non-atrophic maxillary segments was 82 (30.6%), 91 (31.1%), and 124 (28.2%), respectively. One hundred and forty septa (28%) were found to the right side, while 157 (31.4%) were found to the left. The presence and the prevalence of septa in the right and left maxillary sinuses were similar (Table I). Twenty-five patients had multiple septa in five maxillary segments (5%) (Table I): 247 sinuses had 1 septum while 25 sinuses had 2 septa. None of the sinuses examined had 3 septa. In this study, there was no significant difference between the number of septa and gender ($p=0.524$), type of crest ($p=0.686$), and lateralization ($p=0.334$).

Heights

The mean height of the maxillary sinus septa was 4.62 ± 2.50 mm (Table II). The mean height of septa for males was 4.78 ± 2.32 mm and 4.42 ± 2.70 mm for females, respectively. There were no statistically significant differences among the height values of maxillary sinus septa, with regard to gender ($p=0.457$) and lateralization ($p=0.532$). The mean height for the septa was found to be 4.67 ± 2.54 mm in the atrophic maxilla, 4.92 ± 2.68

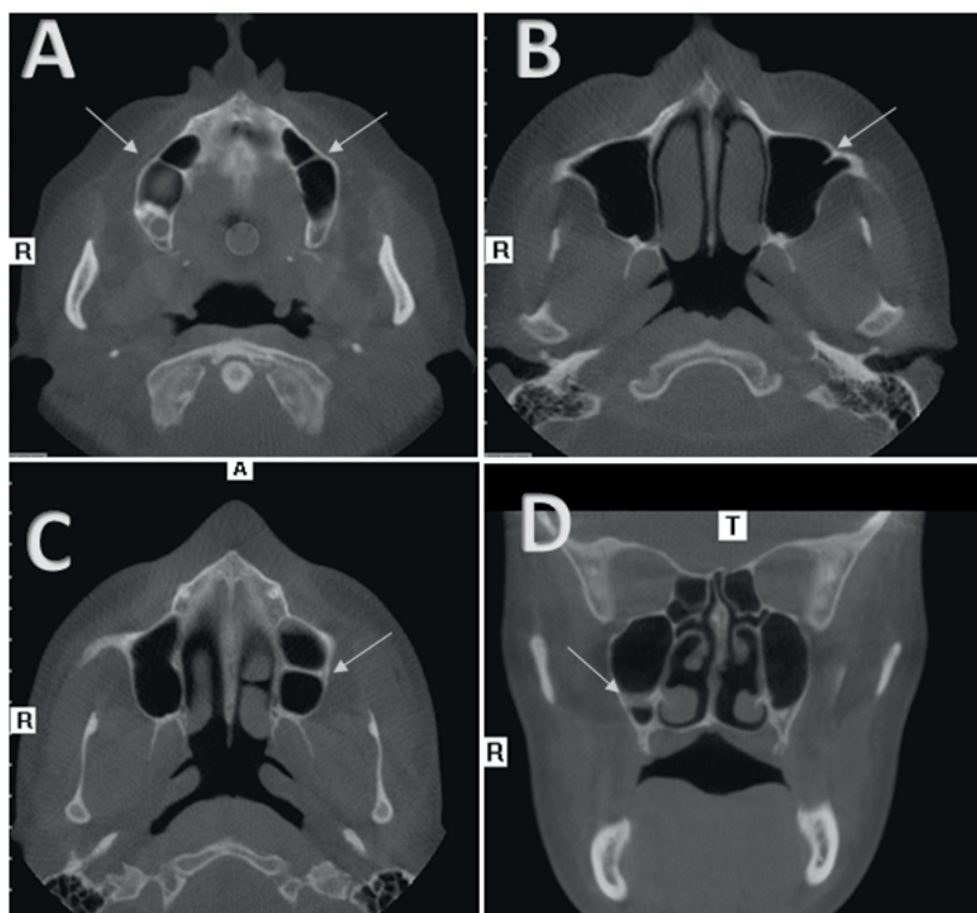


Figure 2. Axial and coronal views of CBCT to determine the presence of maxillary sinus septa. **A**, Mediolateral orientation of septa of both right and left sinuses **B**, Mediolateral orientation of septa in the left sinus **C**, Sagittal orientation of septa in the left sinus **D**, Coronal view, transverse orientation of septa in the right sinus.

Table I. Distribution of sinus septa according to variable groups

Segment of Patients (n)		Septa n (%)	<i>p</i> *
Patients			
Men	552	162 (29.4%)	0.524
Women	448	135 (30.1%)	
Crest type			
Atrophic	268	82 (30.6%)	0.686
Partially atrophic	292	91 (31.1%)	
Non atrophic	440	124 (28.2%)	
Lateralization			
Right	500	140 (28%)	0.334
Left	500	157 (31.4%)	

*presents statistical significance

mm for partially atrophic maxilla and 4.36 ± 2.33 mm in non-atrophic maxilla. There were no significant associations between these groups ($p=0.423$) (Table II).

Location

The analysis of the anatomic location of the septa within the sinus showed that of the 297 (29.7%) septa identified in this study, 44 (8.7%)

Table II. The mean height of septa according to variable groups

	Septa n (%)	Mean height $\pm$ SD	<i>p</i> *
Patients			
Men	62 (29.4%)	4.78 $\pm$ 2.32	0.457
Women	135 (30.2%)	4.42 $\pm$ 2.70	
Crest type			
Atrophic	82 (30.6%)	4.67 $\pm$ 2.54	0.423
Partially atrophic	92 (31.5%)	4.92 $\pm$ 2.68	
Non atrophic	223 (28%)	4.36 $\pm$ 2.33	
Lateralization			
Right	139 (27.2%)	4.65 $\pm$ 2.51	0.532
Left	158 (31.6%)	4.59 $\pm$ 2.50	

*presents statistical significance

Table III. The prevalence of sinus septa according to the anterior- middle -posterior region

	Anterior n (%)	Middle n (%)	Posterior n (%)	<i>p</i> *
Patients				
Men	25 (4.5%)	70 (12.7%)	67 (12.1%)	0.773
Women	19 (4.2%)	53 (11.8%)	64 (14.3%)	
Crest type				
Atrophic	11 (4.1%)	41 (15.3%)	30 (11.2%)	0.266
Partially atrophic	17 (5.8%)	38 (13.0%)	38 (13.0%)	
Non atrophic	16 (3.6%)	44 (10%)	63 (14.3%)	
Lateralization				
Right	18 (3.6%)	61 (12.2%)	60 (12%)	0.407
Left	26 (5.2%)	62 (12.4%)	71 (14.2%)	

*presents statistical significance.

were located in the anterior region, 123 (24.5%) in the middle region, and 131 (26.4%) in the posterior region. The distribution varied when the atrophic, partially atrophic, and non-atrophic maxilla, were compared, but no significant differences between groups were identified ($p=0.266$). According to these results, there were no significant differences between location of septa and gender ($p=0.773$) and lateralization ($p=0.407$) (Table III).

Type

The prevalence of septa located superior to a maxillary tooth in non-atrophic maxilla (primary septa) was 116 (26.4%), while the prevalence of septa located superior to an edentulous ridge (other septa) was 7 (1.6%). In the partially atrophic maxillary segments, the prevalence of primary and other septa was 68 (23.3%) for primary septa, and 24 (8.2%) for other septa (Table IV). However, there was a significant association between the type of septa and lateralization ($p=0.048$), and type of crest ($p=0.001$). No differences were associated with gender ($p=0.837$).

Orientation

Among atrophic maxillary segments, 70 maxillary sinus septa (26.1%) were observed in a mediolateral type orientation, 10 septa (3.7%) were observed with transverse type orientation, and 2 septa (0.2%) were observed with sagittal type orientation. In partially atrophic segments, 78 maxillary sinus septa (26.7%) were observed in a mediolateral type orientation, 11 septa (3.8%) were observed with transverse type orientation, and 3 septa (1.0%) were observed in a sagittal type orientation. In non-atrophic segments, 109 maxillary sinus septa (24.8%) were observed with mediolateral type orientation, 10 septa (2.3%) were observed with transverse type orientation, and 4 septa (0.9%) were observed with sagittal type orientation. In this study, mediolateral septa had the highest frequency (51.4%) while transverse septa (6.2%), and sagittal septa (1.8%) had lower frequency. In a small number of patients (2.4%) with more than 1 septum in each sinus, the septa had various orientations such as mediolateral, transverse and sagittal. Among maxillary sinuses with multiple septa, one septum may be positio-

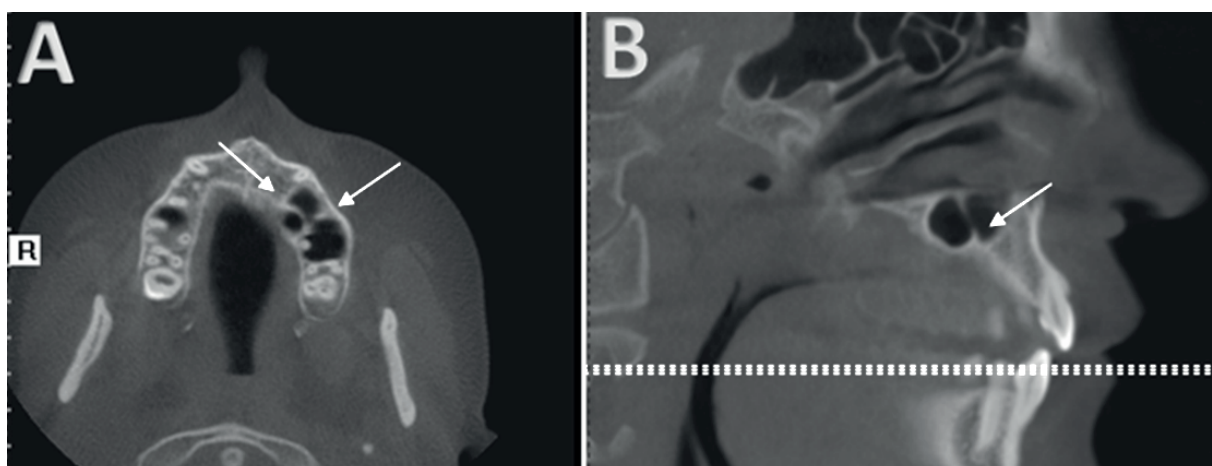


Figure 3. *A*, Axial view of CBCT presented with two maxillary sinus septa (mediolateral and sagittal) *B*, Sagittal view of CBCT presented sagittal orientation of septa.

Table IV. Distribution of sinus septa according to type of septa.

	Primer n (%)	Other n (%)	Total n (%)	<i>p</i> *
Patients				
Men	102 (18.5%)	60 (10.9%)	162 (29.4%)	0.837
Women	89 (19.9%)	46 (10.3%)	135 (30.2%)	
Crest type				
Atrophic	7 (2.6%)	75 (28.0%)	82 (30.6%)	0.001
Partially atrophic	68 (23.3%)	24 (8.2%)	92 (31.5%)	
Non atrophic	116 (26.4%)	7 (1.6%)	123 (28%)	
Lateralization				
Right	98 (19.6%)	41 (8.2%)	39 (27.2%)	0.048
Left	93 (18.6%)	65 (13.0%)	158 (31.6%)	

*presents statistical significance.

ned mediolaterally whereas other septa may be sagittally positioned (Figure 3). In our investigation, there was no significant difference between orientation of septa and gender ($p=0.926$), and type of crest ($p=0.866$). Moreover, orientation of septa in the right and left region, was similar ($p=0.075$) (Table V).

Discussion

Although dental implant therapy is quite predictable and common for treatment of edentulous and partially edentulous patients, additional surgery is often required due to insufficient bone height in the maxillary posterior area. Indeed, sinus floor elevation may be required for placement of implants⁸. However, anatomical variations within the maxillary sinus have been reported to increase the risk of Schneiderian membrane perforation,

and the presence of a sinus septum occasionally becomes the cause of perforation⁷. Radiological evaluation is very important to define and locate the maxillary sinus septa to reduce preoperative and postoperative complications⁷. CBCT images and panoramic radiographs are the most often uti-



Figure 4. Panoramic view of CBCT of both left and right sinuses regions and presence of sinus septa.

Table V. The prevalence of sinus septa according to the orientation.

	Mediolateral n (%)	Transverse n (%)	Sagittal n (%)	<i>p</i> *
Patients				
Men	141 (25.5%)	17 (3.1%)	4 (0.7%)	0.926
Women	116 (25.9%)	14 (3.1%)	5 (1.1%)	
Crest type				
Atrophic	70 (26.1%)	10 (3.7%)	2 (0.7%)	0.866
Partially atrophic	78 (26.7%)	11 (3.8%)	3 (1.0%)	
Non-atrophic	109 (24.8%)	10 (2.3%)	4 (0.9%)	
Lateralization				
Right	125 (25.0%)	13 (2.6%)	1 (0.2%)	0.075
Left	132 (26.4%)	18 (3.6%)	8 (1.6%)	

*presents statistical significance.

lized for preoperative surgical evaluation¹³. However, several authors suggested that panoramic radiography has several limitations such as superimposition and magnification^{7,14}. The structures of maxillary sinus septa are measured in a few millimeters or less in width and height. Advanced imaging techniques with superior resolution such as CBCT can be used to increase detection of these anatomical structures^{7,14,15}. In the last decade, CBCT was recommended for maxillocraniofacial imaging. When comparing absorbed doses, several studies indicate that CBCT imaging is similar to panoramic radiograph, which has requirements that are significantly lower than medical CT scanning¹³. The comparison of the incidence of septa in both radiological techniques indicates that false-negative results are higher in panoramic radiographs^{9,16}. Indeed, Kasabah et al¹⁶ noted that some authors reported up to a 50% false-negative rate. In the present study, we used transverse, axial, and sagittal sections of CBCT images to analyze the features of maxillary sinus septa. Septa were observed in 27.2% of patients and in 29.7% of maxillary sinuses. The prevalence of septa was 29.7%, in which 30.1% were females, 29.4% were males, and 5% of the patients had multiple septa. Krennmair et al¹¹ reported that the prevalence of septa was found in 16% of the sinuses using CT imaging, and Sakhdari et al⁷ reported that the occurrence rate of septa was 44.8% in all patients. We detected the presence of maxillary sinus septa in 82 (30.6%) of atrophic maxillary segments, 91 (31.1%) of partially atrophic maxillary segments, and 124 (28.2%) of non-atrophic maxillary segments. In contrast, Kim et al² reported a significantly higher incidence in atrophic maxillary segments (31.76%) than in non-atrophic maxillary segments (22.61%). Van Zyl et al¹⁷ analyzed 85

dentulous patients and 115 edentulous patients and reported the prevalence of septa in 71%, and 66% of patients, respectively. The difference in prevalence between the edentulous and dentulous groups was important, which might be attributable to the possibility that secondary septa development from the irregular pneumatization of the sinus floor that accompanies tooth loss¹⁰. The primary septa in the non-atrophic maxillary segments were significantly higher than other septa in the atrophic maxillary segments as a result of their growth and were, thus, not likely affected by the resorption of the maxillary alveolar process². An occurrence rate of septa in the left sinus was 157 (31.4%), while in the right sinus was 140 (28%). Velasquez-Plata et al¹⁸ found 72 septa in 312 sinuses, and detected 39 in the left sinus and 36 in the right sinus. Similar to our study, the prevalence of septa was the same at right and left side of patients in recent study¹. Together, these results suggest that lateralization is not an important factor when evaluating the prevalence of septa. Recent researches showed that the prevalence of septa varied from 25% to 70%¹. These differences may be related to the different age of study population and to the differences in radiological imaging technique including CT, CBCT, and two-dimensional (2D) imaging techniques (panoramic radiograph). Our results did not identify significant differences based on gender, dentate status, lateralization, and the prevalence of septa. Similar to our work, Neugebauer et al¹⁹ found no correlation between sex and the prevalence of septa. In the present study, average height of septa was 4.62 ± 2.50 mm. When height was evaluated based on degree of atrophy, atrophic, partially atrophic, and non-atrophic segments, we noted 4.67 ± 2.54 mm, 4.92 ± 2.68 mm, and 4.36 ± 2.33 mm, respectively in height. Howe-

ver, there were no significant differences between these groups. It is important to note that in most of the previous studies, right and left maxillary sinuses were not evaluated separately^{7,20}. Similarly, Krennmair et al⁹ analyzed 82 maxillary sinuses in edentulous region using CBCT, and detected an average height of 4.67±2.54 mm. Prior studies found different heights for the septa ranging from 5.6 mm to 20.6 mm in other study populations^{19,21}. The occurrence rate of septa was highest in the posterior region 131 (26.4%), lower in the middle region 123 (24.5%), and lowest in the anterior region 44 (8.7%). Conversely, Sakhdari et al⁷ reported that the occurrence rate of septa in the middle portion was greater than in the anterior and posterior portion (35.1%), and Krennmair et al⁹ also showed a contradictory result noting that the greatest rate was in the anterior portion of the sinus ranging between 70% and 75%. This discrepancy may be explained by different data collection methods and standardization of the location according to examiners. Further studies will be required to determine the reason for these discrepancies. In our investigation, mediolateral orientation of septa was most common in all groups where 26.1% were identified in atrophic, 26.7% in partially atrophic, and 24.8% in non-atrophic segments. Similar to our research, Koymen et al²² reported that all of the septa identified (46.4%) was oriented mediolateral. Also, previous studies observed mediolateral orientation of septa while sagittal oriented septa were identified less frequent, and the transverse septa were even less frequently^{5,20}. Thus, detection of septa orientation is very important prior to maxillary sinus surgery.

Conclusions

Although other studies have investigated the maxillary sinus septa, to the best of our knowledge no study has evaluated the prevalence, height, localization, type, and orientation of septa according to gender and type of crest. The results of this work show that 27.2% of patients had at least 1 septum in maxillary sinus with different height, localization, type, and orientation. Therefore, CBCT analysis is very important to evaluate maxillary sinus anatomy, including pathology and the presence of septa, before surgery. Furthermore, analyzing CBCT images could be an effective and accurate method for evaluating characteristics of the septa allowing clinicians to more accurately diagnose, more extensively eval-

uate and prevent possible complications during maxillary sinus surgery.

Conflict of interest

The authors declare no conflicts of interest.

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