Surgical and Radiologic Anatomy (2019) 41:1003–1009
https://doi.org/10.1007/s00276-019-02271-2

ORIGINAL ARTICLE

The effects of posterior alveolar bone height on the height of maxillary sinus septa

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Received: 17 January 2019 / Accepted: 21 June 2019 / Published online: 27 June 2019

Abstract

Purpose The purpose of this study was to evaluate whether posterior alveolar bone height affects maxillary sinus septa (MSS) height in dentate and edentulous patients, as determined by cone-beam computed tomography (CBCT).

Materials and methods This retrospective analysis enrolled 166 patients (91 men and 75 women) with a mean age of 43.12 ± 15.26 years (range 18–74 years), who had at least one MSS on CBCT images. MSS were categorized into three regions: anterior, middle, and posterior. Patients were categorized as complete or partial posterior edentulous or fully posterior dentate. The maximum vertical diameter of the sinus septa and alveolar bone height was analyzed in sagittal CBCT sections; $P < 0.05$ was regarded as statistically significant.

Results We found 210 MSS among the patients in this study. Of the 166 patients, 36 had bilateral septa and 4 had three septa. The septa were mainly located in the middle region in the dentate ($n = 70$; 33.3%) and edentulous ($n = 59$; 28.1%) patients. The mean septal height was significantly higher in men than in women ($P = 0.024$). In dentate patients, the mean MSS height was similar among the three regions. In edentulous patients, the anterior mean MSS height (4.96 ± 2.77 mm) was lower than that of the other two regions. There was no statistically significant association between septa and alveolar bone height in any anatomic region, in either group ($r = 0.022$; $P = 0.748$).

Conclusions These results suggest that MSS height is not influenced by alveolar bone height.

Keywords Cone-beam ct · Maxillary sinus septa · Edentulous maxilla · Maxillary sinus floor elevation · Alveolar bone

Introduction

Before performing a sinus membrane elevation procedure, it is important to have detailed knowledge of maxillary sinus floor anatomy to reduce the possibility of membrane perforation and achieve successful sinus augmentation [2, 7]. Maxillary sinus septa (MSS), which constitute anatomical variations in the form of a thin cortical bone that arises from inferior or lateral walls of the sinus cavity, may compromise the integrity of the membrane when elevating it from the sinus floor [1, 10, 24].

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MSS, also known as Underwood's septa, were first described in 1910 and are predominantly located on the sinus floor [23]. A number of theories have been forwarded to explain the development of these septa, and Krennmair et al. [10] classified them as primary or secondary. Notably, they suggested that a primary septum develops during growth of the maxilla, whereas secondary septa result from pneumatization of the sinus floor following posterior tooth loss. Underwood observed that the size of the septa may be increased by further pneumatization of the sinuses following tooth loss [23]; similarly, Vinter et al. [27] claimed that irregular alveolar bone atrophy leads to the formation of bony crests within the sinus cavity. An alternative theory was proposed by van den Bergh et al. [24], who speculated that the septa, extending within alveolar bone to the sinus cavity, constitute cortical struts responsible for the maintenance of masticatory force during the dentate phase of life. Furthermore, they posited that these septa gradually disappear after tooth loss.

Despite these putative explanations, the precise pathophysiology of MSS remains to be clarified. Many studies have assessed the prevalence, location, and size of septa in numerous populations, using various radiographic techniques; these include panoramic radiography, computed tomography (CT), and cone-beam computed tomography (CBCT) [6, 12, 15, 26].

As demonstrated by Sharan and Madjar [20], the extraction of several adjacent posterior maxillary teeth directly affects further pneumatization of the alveolar process. Considering the cause–effect association between alveolar resorption and septa, height differences in sinus floor septa are likely between patients with dentate and edentulous alveolar processes; these may be particularly pronounced in patients with severe alveolar bone resorption, a condition in which septa are suspected to form after pneumatization.

To the best of our knowledge, an anatomical relationship has not yet been established between alveolar bone and the height of sinus septa in dentate and edentulous patients. The purpose of the present study was to analyze the heights of alveolar bone and MSS in CBCT images acquired in various locations, to determine whether there is an association between these anatomic structures in dentate and edentulous patients.

Materials and methods

This study was a retrospective analysis of consecutive maxillary CBCT scans of patients who had been admitted to the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Gaziantep University for various indications, including routine oral surgery (e.g., removal of impacted molars and implant planning), orthognathic surgery planning, or treatment of dental foci. CBCT scans were obtained from the Department of Oral and Maxillofacial Radiology database. The study protocol was approved by the Ethics Committee of Sanko University (June 11, 2018; session: 2018/07, decision no: 1).

Study sample

In the initial review of maxillary sinus CBCT images taken between January 2014 and March 2018, all images showing the maxillary sinus with alveolar bone were included. Images were included if they met the following criteria: (1) buccopalatal-oriented maxillary septa in the axial plane, (2) MSS that originated from the inferior sinus wall and terminated in a sharp edge in the sagittal plane, and (3) septal bone height > 2.5 mm in the sagittal plane [22]. CBCT images were excluded if they met the following criteria: (1) large maxillary pathology, jaw fractures, deeply impacted teeth, previous paranasal intervention, dental implant placement, and/or augmentation; or (2) inadequate scan quality (e.g., low resolution, head movement during exposure, or artifacts caused by metallic implants, screws, or osteosynthesis plates). After detailed examination, this analysis included 166 patients (91 men and 75 women) with a mean age of 43.12 ± 15.26 years (range 18–74 years) who had at least one MSS on CBCT images.

CBCT image acquisition

Images were obtained using a CBCT device (Promax 3D Mid; Planmeca, Helsinki, Finland); the exposure parameters were 90 kVp and 14 mA, with a 15-s scanning time. Reformatted scans were evaluated using the Romexis 3.0.2 software program (Planmeca). All CBCT images were evaluated by the same experienced surgeon (MD) on a desktop UltraSharp LED TFT 24-inch monitor (Dell Inc., Round Rock, TX, USA) with appropriate background lighting. Images were aligned with the nasal spine at the center of the midline in the axial plane, the posterior alveolar bone oriented vertically in coronal slices, and the palatal bone and floor of the nose oriented horizontally in the sagittal plane. Maxillary CBCT scans were obtained from the level of the maxillary tooth crown to the top of the orbit in 1.2-mm intervals.

Localization of MSS

To locate the septa more accurately in sagittal images, the maxillary sinus was divided into three anatomical areas with the teeth as reference points; these areas were based on the protocol by Kim et al. [8]. The three areas were defined as anterior (mesial to 5D), middle (5D–7D), and posterior (7D to distal).

In patients with completely edentulous posterior segments, septa were localized in accordance with the approach used by Gonzales-Santana et al. [3], who divided the sinus into three sections. In the sagittal view, the maximum width of the sinus between the most anterior and posterior walls was divided into three sections (½ of the maximum width for the middle section and ¼ of the maximum width for the anterior and posterior sections) (Fig. 1a).

Measurement of dentate or edentulous alveolar bone and MSS heights

Sinus septa located apically to the maxillary alveolar crest were categorized into three sections (anterior, middle, and posterior), and subcategorized as dentate or edentulous based on the presence or absence of the tooth. To measure

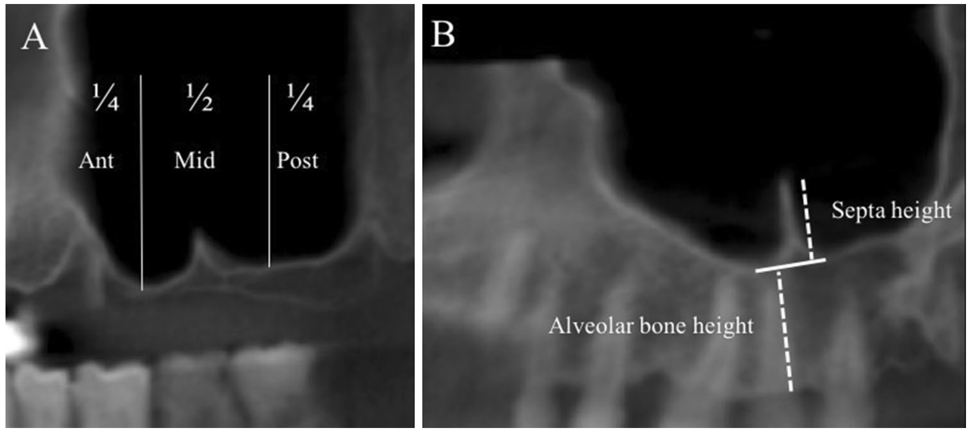

Fig. 1 **a** Localization of maxillary sinus septa in complete posterior edentulous patients. **b** Measurement of alveolar bone and septa heights

the maximum septal height, a perpendicular line was drawn from the highest point of the septum to the septum apex, until it intersected with the line from the deepest point of the septa to the mesial and distal sides [24]. To measure the vertical distance of dentate/edentulous alveolar bone, a straight line was drawn from the most coronal point of the alveolar crest until it intersected with the line from the deepest point of the septa to the mesial and distal sides. These measurements were obtained in the sagittal view and are demonstrated in Fig. 1b.

Data analysis

Descriptive statistics, including the means and standard deviations for each group, and all comparative analyses, were calculated using SPSS for Windows software (version 22.0; IBM Corp., Armonk, NY, USA). Intraoperator reliability for each measurement was assessed using the intraclass correlation coefficient (ICC), with an interval of at least 2 months between measurements; this assessment yielded a 98% agreement rate. Using these replication data, three precision estimates were calculated: inter- and intraobserver technical error of measurement (TEM), relative technical error of measurement (rTEM), and coefficient of reliability (R). TEM constitutes the typical magnitude of error associated with a given measurement and can be used to estimate intraobserver precision. rTEM represents an estimate of error magnitude as a percentage of object size. R represents the proportion of between-subject variance free from measurement error; it ranges from 0 (*not reliable*) to 1 (*completely reliable*) [4, 5, 29].

The Shapiro–Wilk test was applied to determine whether the data had a normal distribution. Pearson's chi-squared correlation coefficient was used to assess relationships between categorical variables. For multiple comparisons, the Kruskal–Wallis and Bonferroni all-pairs tests were used. A significance level of $P < 0.05$ was adopted for all analyses.

Results

The ICC was > 0.98, indicating high intraexaminer concordance. The TEM estimates of septal and alveolar bone height were 0.1207 and 0.3474, respectively. The rTEM estimates of septal and alveolar bone height were 1.73% and 4.18%, respectively. The R for septal and alveolar bone was 0.99.

The final analysis included 166 patients (210 MSS) who had one, two or three septa in the maxillary sinus. Thirty-six patients (12 women and 24 men) had two septa; four patients had three septa. Regarding septal distributions, based on the three anatomic locations in edentulous and dentate patients, 129 septa (61.4%) were found in the middle region; overall, 33.3% of septa were found in the middle region in dentate patients, whereas 28.1% were found in the middle region in edentulous patients. The anterior dentate ($n = 4$; 1.9%) and edentulous regions ($n = 5$; 2.4%) had the lowest prevalence of septa. Regarding location, 111 septa (52.8%) were located on the right side, and 99 (47.2%) on the left side. Patient characteristics are shown in Table 1.

The mean septal height in male and female patients was 7.23 ± 2.67 mm and 6.57 ± 3.03 mm, respectively. The difference in mean septal height was statistically significant between sexes ($P = 0.024$; Table 2). The mean septal height in the middle region was 6.87 ± 2.45 mm and 7.41 ± 3.05 mm for dentate and edentulous patients, respectively. These values were higher than those of the posterior and anterior regions in each group. Each region in the dentate group had higher mean alveolar bone heights (anterior: 14.36 ± 3.17 mm; middle: 9.73 ± 3.29 mm; and posterior: 9.40 ± 4.24 mm) compared with those of the edentulous group (anterior: 6.81 ± 3.53 mm; middle: 5.96 ± 3.68 mm; and posterior: 7.86 ± 2.88 mm), as expected. In both groups,

Table 1 Male and female patients' characteristics

	Patients	
	Male	Female
Age (years)		
Mean ± SD	43.44 ± 14.18	42.85 ± 16.18
No. of septa per sinus (*n*/%)		
1 (126/75.9%)	65 (39.1%)	61 (36.8%)
2 (36/21.6%)	24 (14.4%)	12 (7.2%)
3 (4/2.5%)	2 (1.25%)	2 (1.25%)
Total (166/100%)	91 (54.75%)	75 (45.25%)
Side (*n*/%)		
Right (111/52.8%)	58 (27.6%)	53 (25.2%)
Left (99/47.2%)	61 (29%)	38 (18.2%)
Total (210/100%)	119 (56.6%)	91 (43.4%)
Location (*n*/%)		
Anterior (9/4.4%)	6 (2.9%)	3 (1.5%)
Middle (129/61.3%)	74 (35.2%)	55 (26.1%)
Posterior (72/34.3%)	40 (19%)	32 (15.3%)
Total (210/100%)	120 (57.1%)	90 (42.9%)

SD standard deviation

Table 2 Distribution of maxillary sinus septa heights according to gender

	Male	Female	*P*
Septa height (mm)	7.23 ± 2.67	6.57 ± 3.03	0.024*

*$P < 0.05$ statistically significant

the difference in alveolar bone height among the anterior, middle, and posterior regions was statistically significant (dentate: $P = 0.01$; edentulous: $P = 0.007$; Table 3).

No statistically significant association was found between septal and alveolar bone height, in any anatomic region in either group ($r = 0.022$; $P = 0.748$; Fig. 2).

Discussion

MSS are regarded as anatomical structural variations within the sinus cavity, for which surgical intervention is generally not needed. However, the clinical importance of MSS orientation, location, and height with regard to the sinus floor has gained attention in recent decades, due to the increased use of sinus membrane elevation to increase alveolar bone height. Therefore, multiple recent studies have examined and reported on the prevalence, location, shape, and height of MSS, and have given various explanations regarding the underlying mechanism [6, 8, 9, 12, 15, 21, 22, 26]. Until now, no study has focused on the relationship between posterior maxillary alveolar bone height and the height of sinus septa in dentate or edentulous patients. The present study did not reveal a statistically significant association between the heights of MSS and alveolar bone in any anatomic region (anterior, middle, or posterior), either for dentate or edentulous patients ($P = 0.748$; $r = 0.022$).

Some authors have suggested that early loss of teeth, including the first and second molar in the middle region, seems to induce irregular pneumatization of the sinus floor to the alveolar crest; this may contribute to the development of secondary septa [10, 11, 26]. Conversely, a recent study by Wagner et al. [28] revealed that the change in alveolar

Table 3 Distribution of alveolar bone and septa heights according to anterior (-5D), middle (5D–7D), and posterior (7D-) maxillary sinus regions in dentate and edentulous patients

	Localization			
	Anterior (-5D) Mean ± SD	Middle (5D–7D) Mean ± SD	Posterior (7D-) Mean ± SD	*P*
Dentate (*n* = 104)				
Alveolar bone height	14.36 ± 3.17	9.73 ± 3.29	9.40 ± 4.24	0.010*
Septa height	6.53 ± 1.85	6.87 ± 2.45	6.09 ± 2.21	0.285
(*n*/%)	*n* = 4/1.9	*n* = 70/33.3	*n* = 30/14.3	
Edentulous (*n* = 106)				
Alveolar bone height	6.81 ± 3.53	5.96 ± 3.68	7.86 ± 2.88	0.007*
Septa height	4.96 ± 2.77	7.41 ± 3.05	7.29 ± 3.52	0.181
(*n*/%)	*n* = 5/2.4	*n* = 59/28.1	*n* = 42/20	
n = 210				
Total (*n*/%)	*n* = 9/4.3	*n* = 129/61.4	*n* = 72/34.3	

SD standard deviation

*$P < 0.05$ statistically significant

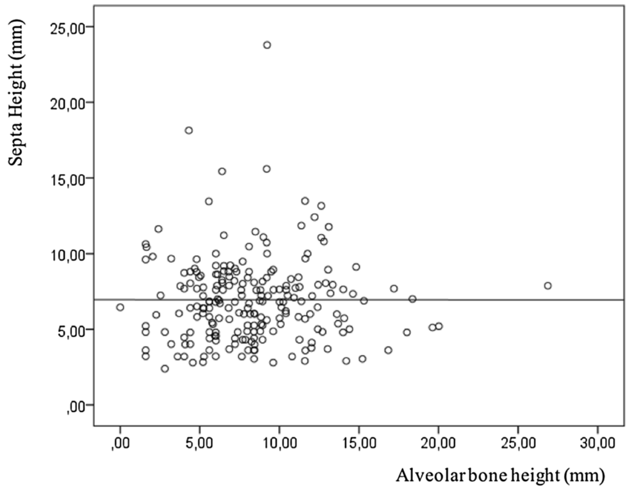

Fig. 2 Correlation of the maxillary sinus septa height (mm) with alveolar bone height (mm) in all anatomic regions of each group. Pearson correlation ($r = 0.022$, $P = 0.748$)

bone height is primarily caused by tooth loss, rather than sinus pneumatization to the alveolar crest; this assertion is supported by our findings (i.e., the mean difference in septal height in the middle and posterior regions, between dentate and edentulous regions, was 0.54 and 1.2 mm, respectively). Septal height in edentulous regions (middle and posterior) was slightly higher than in dentate regions; this finding is similar to that reported by Jang [6], who found no significant difference between edentulous (5.30 ± 1.90 mm) and dentate (6.0 ± 2.21 mm) patients. We speculate that the so-called primary sinus septa are largely formed during growth of the maxillary sinus, rather than after irregular pneumatization following tooth loss. In addition, it is not possible for clinicians to determine the exact occurrence of secondary septa, as they cannot distinguish between primary and secondary septa if radiographs are not taken prior to tooth loss—secondary septa might be formed before tooth loss [19]. Therefore, the assumption that secondary septa form after irregular sinus pneumatization, first claimed by Krennmair et al. [10] and later supported by other authors [11, 26], may need to be reevaluated, based on the findings of Wagner et al. [28] and those of the present study. Based on logistic regression analysis, Shen et al. [21] suggested that tooth loss might not increase the occurrence of secondary septa. This result was consistent with the findings of the present study, which revealed a nearly equal distribution of septa between dentate (49.5%) and edentulous (50.5%) patients.

Only nine anterior sinus septa, comprising 4.3% of the overall sample, were identified by CBCT in the present study. However, this anterior frequency was markedly lower than that of other studies, in which the frequency varied from 15.98 to 58.3% based on differences in the methods used to localize sinus septa [6, 12, 13, 15–17, 21]. With respect to the distribution of septa in dentate and edentulous patients, the present study revealed that the middle region had the highest frequency of septa in both groups (33.3% in dentate and 28.1% in edentulous). The predominant septal location may vary among studies. Rancitella et al. [17] found that primary septa were present in anterior and middle regions in dentate patients, whereas they were present in posterior regions in edentulous patients; this finding was similar to that of the report by Underwood [23]. However, it is evident that the middle region is predominant in many studies, with a frequency between 34.9 and 54.12%, according to differences in measurement methods, data collection methods, and study populations [6, 15, 16, 21, 26].

The present study found no statistically significant difference in the mean height of septa among the anterior, middle, and posterior regions, in either dentate or edentulous patients. The edentulous anterior region had the lowest septal height (4.96 ± 2.77 mm), while the highest septa were found in the edentulous middle region (7.41 ± 3.05 mm). When comparing our findings with those of other studies, some discrepancies arose regarding measurement techniques for CT or CBCT analyses. Velásquez-Plata et al. [26] and Kim et al. [8] measured each septum at three points: lateral, central, and medial. In some studies, the mean septal height was considered to be the overall mean height, irrespective of anatomic region or sinus side [10, 26]. The data in the literature have little comparative clinical value because of differences in data collection methods, in terms of right or left sinus separation, edentulous status, and septal measurement technique. Nonetheless, the mean septal height in each of the subgroups in this study was consistent with those reported by Jang et al. [6] (overall mean septal height in dentate and edentulous patients: 6.01 ± 2.21 mm and 5.30 ± 1.9 mm, respectively), Qian et al. [16] (mean height of lateral, middle, and medial regions: 4.39, 5.56, and 6.44 mm, respectively), and van Zyl and van Heerden [24] (overall mean septal height: 6.2 mm).

Regarding sex differences, men had a higher prevalence of septa than women in this study. This finding was consistent with that of Shen et al. [21], but inconsistent with the results of Shakhdari et al. [18] and Qian et al. [16]. We found a statistically significant difference in mean sinus septal height between men and women ($P = 0.024$).

The present study had some limitations. First, because of the retrospective nature of the CBCT analysis, there were no data regarding the date of tooth extraction in edentulous patients. Long-term edentulism is known to affect ongoing resorption of the alveolar process. This may have biased the outcomes, although only CBCT sections that reflected complete bone healing in edentulous alveolar regions were included. In addition, there was a lack of information regarding denture usage or the presence of systemic diseases that affect bone healing.

Knowledge of the presence of MSS is of critical importance when planning sinus membrane elevation surgery. If septal height increases, the surgical procedure may become more complex, due to close attachment of the membrane to septal bone. In some circumstances, for example when septa are present in the trap-door, two separate trap-doors could be prepared if surgical access is limited, or if difficulty arises when inserting the bone graft into the sinus cavity. To reduce or avoid the risk of membrane perforation, its location, size, and orientation should be assessed using CT or CBCT, as these methods provide improved diagnostic imaging of maxillary bone anatomy and three-dimensional reconstruction relative to conventional radiographs [6, 7, 12, 14, 25].

The present study revealed that MSS height is independent of vertical alveolar bone resorption. Moreover, secondary septa in edentulous patients may, in fact, constitute primary septa.

Author contributions MD and ND: design and protocol development, MD: data collection and management, MD and ND: data analysis and manuscript writing/editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest with the contents of present article.

Ethical approval Ethical approval was obtained from the Ethics Committee of Sanko University, Gaziantep, Turkey (June 11, 2018; session: 2018/07, decision no: 1).

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