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AQ2 ANATOMIC STUDY

Maxillary Sinus Septa and Anatomic Correlation With the Schneiderian Membrane: An Evaluation of 114 CBCT

Davide Rancitelli, DDS, Andrea Enrico Borgonovo, MD, DMD,* Marco Cicciù, DDS, PhD,† Dino Re, MD, DDS,‡ Federica Rizza, DDS,‡ Anna Chiara Frigo, MSc,§ and Carlo Maiorana, MD, DDS**

AQ4

Abstract: Aim of this investigation is to evaluate prevalence, localization, and height of 114 maxillary sinus septa by using cone-beam computed tomography scans. The thickness of the mucosa has been measured together with the variations of the membrane in relation to those septa.

A total of 228 maxillary sinuses have been considered. Septa were identified using "panorex" reconstructions and axial scans of cone-beam computed tomography using the software "eXam-Vision." The thickness of the mucosa has been evaluated in the paraxial scans and related to those septa where they were present.

In the current study, the prevalence of sinus septa is 38.1%. Significant difference can be found in the height of primary and secondary septa. The mean height of primary septa was 5.5 mm (±1.19) and of secondary septa 3.4 mm (±1.6). Anterior and medium septa resulted significantly higher than posterior septa ($P = 0.003$). The medium thickness of the mucosa was 0.85 mm (±0.58), whereas close to the septa it turned out to be 1.8 mm (±1.87). The difference is statistically relevant ($P = 0.003$). There is no statistically significant proportional relation between dimensions of septa and thickness of mucosa ($P = 0.53$).

Underwood septa are frequent anatomic variations of the maxillary sinus. Their presence may result in a thickening of the sinus membrane. The systematic study of radiographic anatomy of maxillary sinus is necessary before the sinus lift surgery planning.

Key Words: Cone-beam computed tomography, maxillary sinus, Schneider membrane, septa

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The maxillary sinus is a large pyramidal cavity with thin walls corresponding to orbital, alveolar, facial, and infratemporal aspects of the maxilla. The size, shape, and wall thickness of the sinus varies from one to another even on the 2 sides of an individual skull.[1]

Maxillary septa are walls of cortical bone within the maxillary sinus. The septa shape has been described by Underwood as an inverted gothic arch arising from the inferior or lateral walls of the sinus and may even divide the sinus into 2 or more cavities. The presence of bone septa on the sinus floor is an anatomic condition that may increase the risk of perforations in the maxillary sinus elevation.[2,3]

Septa are divided in 2 different types depending on their origin. The first type is congenital and arises during development of the maxilla. Secondary type derives from tooth loss and an irregular pneumatization of the sinus floor.[4]

It is important to identify these structures because of preoperative prevention of any surgical complication (Fig. 1).

The normal thickness of the Schneiderian membrane is approximately 1 mm. Mucosal thickening of the maxillary sinus, however, is common in asymptomatic patients[5]; therefore, the mucosal lining is considered to be normal up to 4 mm.

The purpose of this study was to determine the prevalence, height, and localization of maxillary sinus septa using cone-beam computed tomography (CBCT) scan and by comparing the variation of mucosa in relation to these septa. Even though there are many studies regarding anatomic variation of maxillary sinus, just a few of them are concerned with the relation between septa and Schneiderian membrane; moreover, the anatomic knowledge of maxillary sinus is fundamental to plan its surgical lift avoiding possible complications, such as the perforation of the membrane that could be caused by the presence of those anatomic variations. Sinus augmentation has evolved into a predictable surgical technique for increasing the residual ridge height with bone of sufficient quality to allow successful positioning of dental implants. Sinus floor augmentation can today be considered a relatively safe procedure, but severe complications may occur as a result of incorrect surgical plan or related to aggressive surgical maneuvers. The success of this technique cannot be far from a correct preoperative planning. Moreover, the CBCT technique is a valid device for underlining all of the anatomic limits and for avoiding all of the possible difficulties that clinicians may undergo during this surgery. For this reason, this article is focused on the importance of the evaluation of radiologic investigation through the sinus anatomy.

MATERIAL AND METHODS

In this study, 114 CBCT examinations and 220 maxillary sinuses were analyzed. All of the collected data remained anonymous. The data collection was carried out from May 2012 to September 2013. The 114 examinations were randomly evaluated.

The selected patients received a CT scan in the posterior maxilla for implant therapy or for other evaluation as impacted canine. Postoperative thyroid carcinoma examinations of maxillary sinuses after sinus elevation were excluded from the sample. The sample AQ5

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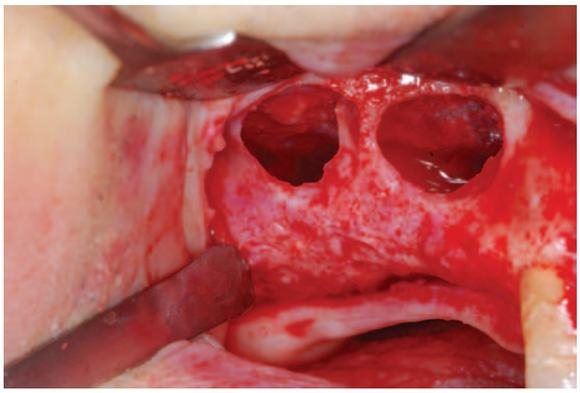


FIGURE 1. Sample of clinical view of sinus septa during sinus lift surgery.

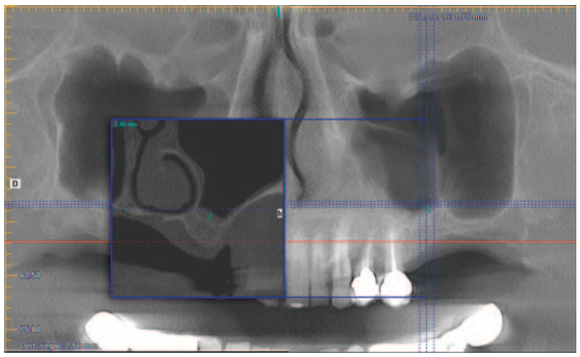


FIGURE 3. Evaluation of the thickness of the membrane in the presence of septum in "Panorex" reconstruction; the measure of membrane in the paraxial cut is highlighted in detail.

consisted of 72 women and 42 men of an age range of 5 to 77 years (mean age 49 years).

From the tomography, sinuses were evaluated through axial cuts and "panoramic" reconstructions using the dedicated software "eXamVision" in DICOM (Digital Imaging and Communications in Medicine) format.

The maximum height of each septum was measured in "Panorex" cuts after the check of its presence in the axial projection; 0.5 mm scans were adopted.

To measure the maximum height, a line connecting the deepest point mesial and distal to the septum was designed, and the perpendicular to this segment was later traced from the apex of the septum, as in the study by van Zyl and van Heerden[6] (Figs. 2 and 3).

The thickness of the mucosa was measured in the paraxial projections with 2 mm scans. The parameters of the examination were kV = 120, mA = 5, and field of view = 140 × 170 mm.

The thickness of Schneider membrane was evaluated on paraxial images, and as reference point was used the deepest point of the convex sinus inferior border, basing on the method of Cakur et al.[5]

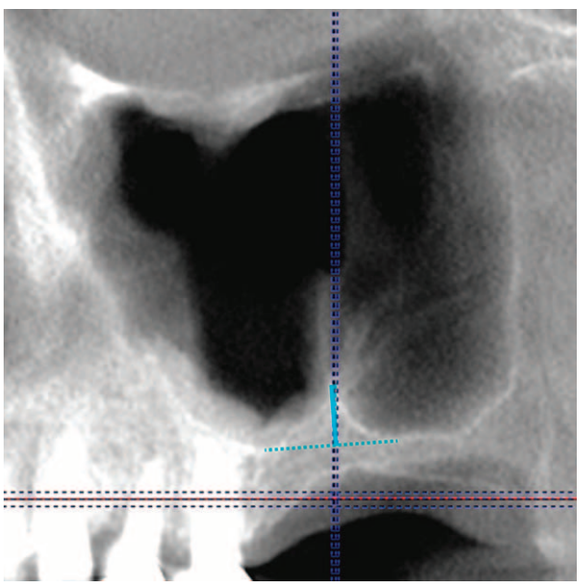


FIGURE 2. Evaluation of septa in the axial projection.

The considered measure was the highest one referred to the perpendicular line to the sinus floor according to Bernstein indica- The values >6 mm were not considered because the presence of the radiographic images alone did not allow a correct study on the physiological value of the membrane. Moreover, the radiographic data without any clinical support were not sufficient to attribute these values to the presence of septa.

In the presence of septa, the measurements were double, one perpendicular to the septum and the other one located far from it. At the end these data were compared. There was not any exclusive minimum size of septa (Figs. 4 and 5).

Localization of each septum (anterior, middle, or posterior) was recorded, using teeth as reference points.

Septum was considered to be localized in the anterior region when mesial to the root of the second premolar, in the middle region when mesial to the distobuccal root of the second molar and the distal root of the second premolar, and in the posterior region when distal to distobuccal root of the second molar[8–10] (Fig. 6).

Patients in whom dental elements are absent, the localization was obtained following the method of González-Santana et al,[11–13] which intends to divide the sinus into 3 parts: the maximum width was traced in Panorex cuts from the anterior wall to the posterior wall of the sinus, and it was divided maintaining proportions of $^1/_2$ of the width for the middle part and 1/4 for the anterior and posterior ones.

The septa were classified into primary and secondary; the first ones were located over a maxillary tooth, whereas the second ones were located over an edentulous ridge following the method of Krennmair et al.[14]

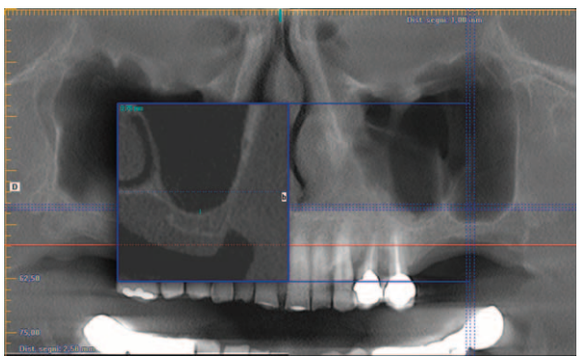


FIGURE 4. Evaluation of the thickness of the membrane far from the septum; the measure of membrane in the paraxial cut is highlighted in detail.

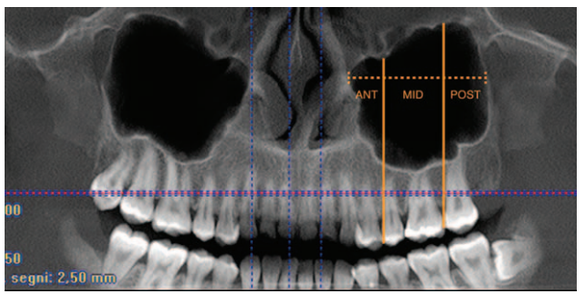


FIGURE 5. Classification of septa in the presence of teeth.

Despite that, the authors underline how it is impossible to classify the septa as primary or secondary without a radiographic history of this anatomic condition when it is localized over an edentulous ridge; in fact, those located apical to an edentulous region can be either primary or secondary. Controversially, despite the absence of radiographic history, it has been suggested that anatomic criteria could help the observer to classify them, such as irregular sinus floor and massive pneumatization.

It is important to highlight that in case of septa localization apical to an edentulous ridge, they could be either primary or secondary, but it is impossible to distinguish them with certainty without a radiographic history of the sinus; nevertheless, it has been suggested that there are anatomic criteria that could help the observer to classify them, such as irregular sinus floor and massive pneumatization.

All of the data were analyzed as univariate and nonparametric analysis using the SPSS statistics program (SPSS v11.0; SPSS Inc, Chicago, IL).

Evaluation of Statistical Significance Between Thickness of the Membrane in Absence of Septa and Thickness of the Membrane Perpendicular to Them

The difference between the 2 thicknesses was evaluated, and the nonparametric test of Wilcoxon signed-rank was applied because the Shapiro-Wilk test determined the not normality of the distribution.

Evaluation of the Difference of the Height Between Primary and Secondary Septa

The mixed-model analysis of variance has been used. Because there were multiple measures in the same patient, it has been applied for the models of the type of septa (primary/secondary) and the measure for the patient (1/2/3), whereas a compound symmetry has been considered for the variance and the covariance.

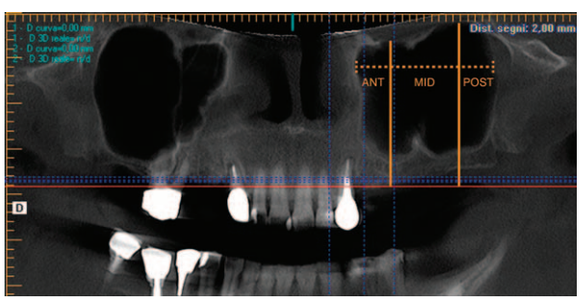


FIGURE 6. Division of edentulous sinuses for the classification of septa.

The results were expressed as value of statistical significance, as average in each of the 2 groups with the relative 95% confidence interval, and as difference between these averages estimated with minimum squares method.

Evaluation of the Height of Septa Grouped Together Depending on Their Localization

The height distribution was not normal (Shapiro-Wilk test); hence, the analysis has been done applying the nonparametric test of Kruskal-Wallis followed by the Dunn test to compare 2 by 2 in each group in case of statistical significance.

Evaluation of Correlation Between the Height of Septa and the Thickness of Mucosa

The analysis of correlation has been done through the nonparametric Spearman coefficient because of the not normality distribution of the heights of septa and the thickness of membranes (Shapiro-Wilk test).

RESULTS

Prevalence of Septa

Sinuses with septa were 87 of the 228 (38.1%), sinuses without septa were 141 (61.9%), but, considering the patient, it turned out that 63 patients had septa (55%).

Distribution of Septa in Patients

Female patients presenting septa were 36 (46% of female patients); male patients presenting septa were 28 (66.7% of male patients). The unilateral septa were present in 39 patients (62%), and bilateral septa were present in 24 patients (38%). Sinuses with only 1 septum were 81 and with 2 septa were 6.

Localization of Septa

In CBCT results, anterior septa were 28 (29.4%), medium (35.7%), and posterior 33 (34.7%). AQ10

Primary and Secondary Septa

In the CBCT, the number of primary septa were 60 (63.1%) and secondary were 35 (36.9%). Primary septa in CBCT are 36% anterior, 31% medium, and 33% posterior. The range value of septa was 1.2 to 21 mm.

Measurement of Septa

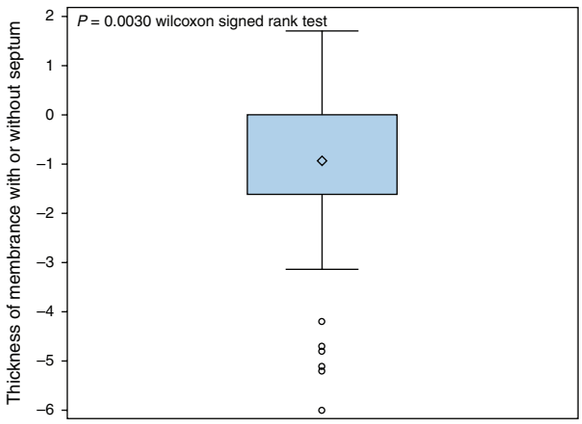
The medium height of primary septa was 5.5 mm (95% CI 3.1–7.8 mm); the medium height of secondary septa was 3.4 mm (95% CI 0.76–6.06 mm). AQ11

The difference between averages is 2.1 mm (95% CI 0.3–3.8 mm). This difference is statistically significant ($P = 0.0177$). The medium height of anterior septa was 7.02 mm (±4.01), medium septa was 7.13 mm (±4.17), and posterior septa was 4.38 mm (±2.00).

Sinus Membrane

The mean value of thickness of the mucosa in absence of septa in the study is 0.85 mm (±0.58) instead of 1.8 mm (±1.87) close to septa. The difference between the averages is −0.94 mm (±1.9). The difference of thickness is statistically significant ($P < 0.003$) (Wilcoxon signed-rank test).

The patients who presented a thickening >6 mm in the absence of septa were 20 of the 228 (17.5%). The patients who presented a thickening >6 mm in the presence of septa were 15 of the 64 (23.4%) (Fig. 7). AQ12



AQ17 **FIGURE 7.** Difference of the membrane height in the absence or in the correspondence of septa: box and whisker plots; the limits of the boxes represent the first and the third quartile, respectively. Whiskers are the minimum and the maximum, while 1.5 is the distance of the interquartile range in the box. The median value is indicated by horizontal lines and mean value is indicated by the diamond. The circles represent the extreme values.

Correlating the thickness of the membrane and the height of septa, it was found that there is no statistically significant correlation, which demonstrates a proportional increase of thickness of mucosa and height of septum.

DISCUSSION

The relation between the Schneiderian membrane and the Underwood septa is a critical element for the success of the sinus floor elevation surgery[15]; the presence of anatomic variations was reported to increase the risk of membrane perforation, which is the most common intraoperative complication of this procedure.[8,9,16,17] Moreover, in this case, the risk of postoperative complication can rise up to 44% and always threatens the coverage of the bone graft.[6,18–20] It was reported that the prevalence of antral septa varies between 13% and 35.3% in studies based on the number of sinuses, and between 21.6% and 66.7% in those based on the number of patients.[13] According to Vlassis and Fugazzotto,[21] perforation occurs more frequently during osteotomy than during the reflection of the membrane. If a sinus lift is conducted in the presence of septa, then it may be necessary to modify the design of the lateral window to avoid fracturing the septa and perforating the membrane.

In 1910, Underwood[22] published a detailed description of maxillary sinus anatomy, evidencing antral septa of varying shape and size, and based his study on 45 anatomic preparations. Krennmair et al[14] divided septa into primary and secondary on another Septa classification: primary septa correspond to those first described by Underwood, which arise from the development of the maxilla, whereas secondary septa arise from irregular pneumatization of the sinus floor following tooth loss.

In the present CBCT study, the prevalence of septa in the maxillary sinuses was 38, 1% higher than the value found in other studies.[9–14] In the study by Maestre-Ferrín et al,[13] there was a higher prevalence of antral septa (58.3%), despite the exclusion of the septa with vertical measurement below 2.5 mm, criteria used for the first time from the study by Ulm.[12]

The study of van Zyl and van Heerden[6] recorded a prevalence of 56% of septa even if the authors did not present any exclusion criteria of minimum height. It was related to the possibility that even very low septa can change the elevation of the sinus floor, especially for inexperienced surgeons.

In the current study, when considering patients, instead of sinuses, the prevalence was 55%. This was similar to the prevalence determined by Underwood,[22] but higher than the results of the studies by Kim et al,[9] Velásquez-Plata et al[10], González-Santana et al,[11] and Shibli et al.[19] AQ14

Some studies have shown more frequently the presence of septa in the middle region,[8,9] for the others[12] the most frequent localization was the anterior region, whereas only for the study by Underwood[22] the more frequent localization turned out to be the posterior one.

In this study, the distribution is rather homogeneous but with a light prevalence in the medium region. A different localization was noticed, when considering septa according to their origin: the primary septa were more present in the anterior and middle localizations, whereas the secondary septa were frequently posteriors. This is because the secondary septa derive from the tooth loss, and the area of the third molar was most frequently associated with those anatomic conditions.[9] Krennmair[8] and Velásquez-Plata et al[10] report that atrophic sinuses present mainly secondary septa, whereas no atrophic areas have even a minor presence of bone septa. AQ15

The mean height of the septa in this study was 4.53 mm (±0.29) and ranged between 1 and 21 mm. These values were similar to the data found in the literature: Underwood reported heights ranging from 6.4 to 12.7 mm, González-Santana et al between 2.5 mm and 6 mm, van Zyl and van Heerden a mean height of 6.2 mm. The study by Maestre-Ferrín et al[23] and did not highlight any significant difference in the heights, neither in different localization, nor in primary or secondary origin. The reported mean height of the septa was 4.78 mm.

The current study found a statistically significant difference ($P = 0.0177$) between the heights of primary and secondary septa. The mean height of a primary septa was 5.5 mm (95% CI 3.1–7.8 mm) and of a secondary septa was 3.4 mm (95% CI 0.7–6 mm). The average value difference was 2.1 mm. The variability of membrane in relation to septa compared to the measure of the membrane on the sinus floor was evaluated. The comparison highlighted that there was statistical significant difference ($P < 0.003$) between the thickness of the membrane close to septa and the thickness of the membrane measured far from septa. Among the few studies that have evaluated this correlation in literature can be mentioned the work by Cakur et al[5] in 2013, which examine the relation among the Schneiderian membrane, Underwood septa, and the maxillary sinus inferior border.

This study, through the Pearson correlation analysis, compared these 3 variables on a sample of 74 patients and 144 sinuses. Consequent to the performed analyses, it was found that there was only a negative correlation between septa and membrane thickness ($r = -0.168$, $P = 0.042$).

In the current study, instead, the investigation method to evaluate the relation between these variables was completely different because it carried out different measures in the same sinus.

From the investigation, the thickness of the mucosa close to septa was highly significant ($P < 0.003$), and it was believed that this anatomic variation could determinate a stall of the mucociliar clearance with consequent reactive phenomenon.

Another study by Shanbhag et al[24] in 2013 examined the thickness and the morphology of Schneiderian membrane underlying that membrane thickness >2 mm is prevalent in 60% of patients with polypoid type in 38% of cases.

In the current study, the prevalence of patients with membrane thickening over the physiological value was 20% to 23%. We remind that the cutoff value that we fixed in the protocol was 6 mm. We can deduce that there is a similitude with the Shanbhag study underlying a frequent thickening of the mucosa even in the absence of clinical symptoms.

A positive correlation between the height of septa and the thickness of membrane was not found, but according to the literature,[7] the thickness of mucosa is rather variable. Furthermore, studies will be necessary to enhance this aspect.

Sinus lift surgical procedures require knowledge of the maxillary sinus anatomy. This cavity is highly different in every patient, and it has anatomic difference also from one to the other side.

Underwood septa are remarkable anatomic variations and present a wide range of possible heights. From our study, it has been highlighted that the anterior-medium portion of the sinus is that with statistically higher septa.

The secondary septa are usually 2.1 mm smaller than the primary ones and are located in the posterior region.

The statistical analysis highlighted that the value of the thickness of the membrane in the presence of septa is almost double compared with the one evaluated far from septa.

A positive correlation between height of septa and thickness of membrane was not found; moreover, the thickness of mucosa is rather variable.

It was reported in literature that the incidence of perforation is higher when the thickness of the membrane is <1 mm.[25]

According to the data from the current study, the membrane close to septa is more than this critical value; hence, considering the prevalent anterior-medium location of the highest septa, it can be suggested that in a patient having a considerable maxillary sinus septum, a ''double trapdoor'' design of the antrostomy and an exposition of the septa as a ''new wall'' of the sinus could limit the risk of perforation. Following other articles published in 1993,[4] 2006,[9] 2012,[25] and 2013,[5] the diagnosis of the septa presence is fundamental to avoid surgical complications. The high numbers of wrong diagnosis by using just the panoramic investigation highlights how the sinus anatomic extensions cannot be entirely evaluated. Other devices such as, CT scan, three-dimensional and cone beam, represent today the better diagnostic systems for having the real maxillary anatomy and not only. Cone-beam CT and subsequent three-dimensional reconstructions consent high-resolution imaging of anatomic bone structures and can be considered the method of choice for imagining and investigating sinus anatomy. Axial section perpendicular tracks are requested for evaluating the septa orientation. Moreover, clinicians should request the axial section to examine this bony structure before surgery.

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